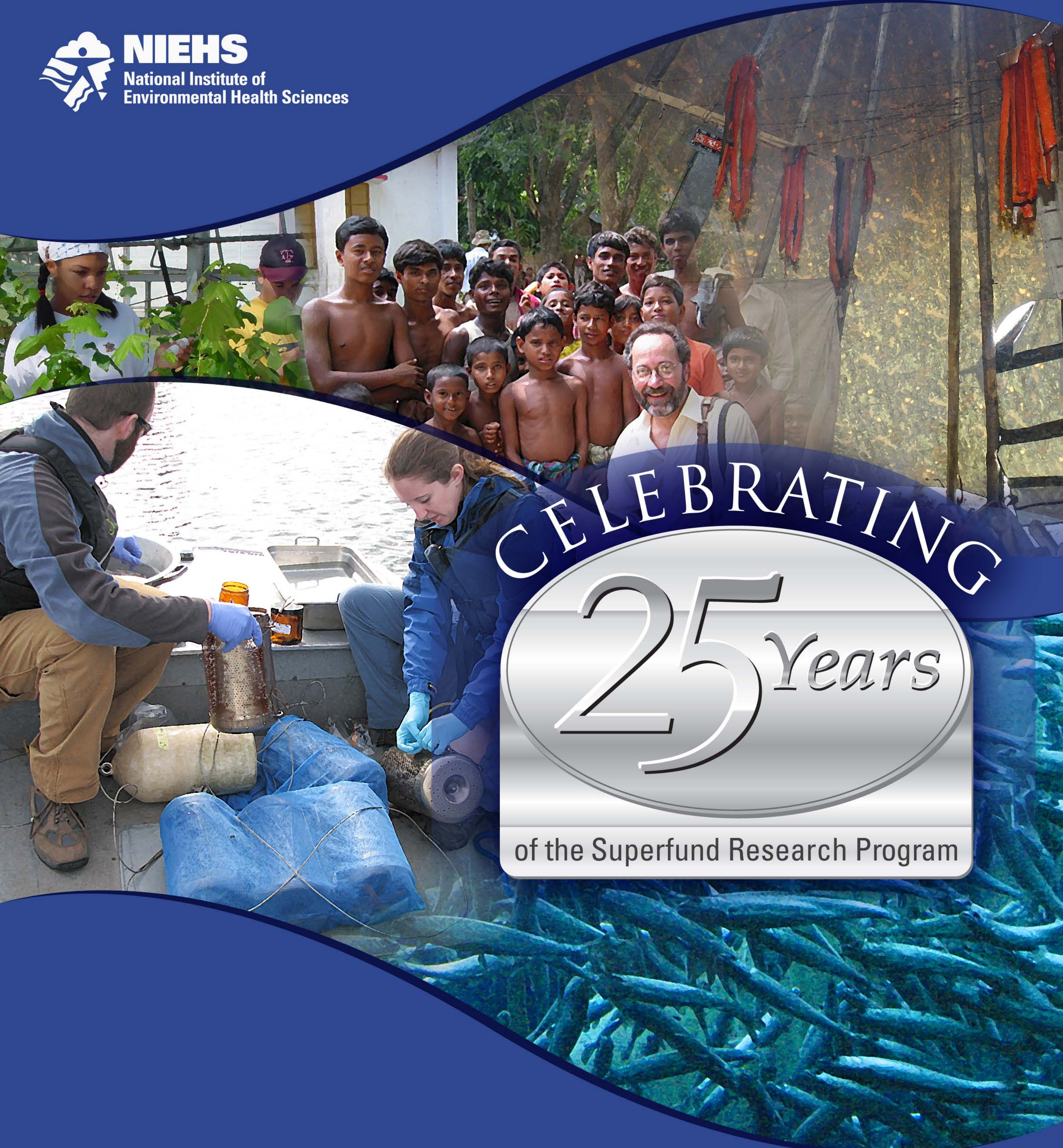
NIEHS
National Institute of
Environmental Health Sciences



Celebrating 25 Years of the Superfund Research Program

DEPARTMENT OF HEALTH & HUMAN SERVICES USA

NATIONAL INSTITUTES OF HEALTH

NIH...Turning Discovery Into Health®

Celebrating 25 Years

of the Superfund Research Program

U.S. Department of Health and Human Services
National Institutes of Health
National Institute of Environmental Health Sciences

CELEBRATING 25 Years of the Superfund Research Program

As the founding Director of the Superfund Research Program (SRP), I am humbled when I reflect on the fine science of this landmark Program and the many impacts that SRP science has had in diverse fields. It has been exciting to be part of the growth and evolution of this impressive Program and to have the opportunity to work with such an august group of investigators. In the following pages, I share with you some observations of colleagues and highlight a few examples of grantee success stories, which I hope capture why am so proud to be a part of the SRP.

When the SRP was established in 1987, bridging biomedical and engineering fields was a major innovation. The leading-edge SRP pursues discoveries at the boundaries where scientific disciplines meet and innovation is essential. This pioneering nature of the SRP has attracted a broad group of the nation's top environmental and public health researchers and stakeholders.

The SRP has a distinguished record of accomplishment and a promising future for tackling new environmental, public health, and scientific challenges to advance original research and achieve momentous and influential impacts. The SRP work informs environmental risk assessment, develops technologies that measure or improve remediation of hazardous chemicals, and provides outreach and translation activities to engage communities and other stakeholders. From biomedical basic researchers to field engineers, the SRP also pushes the bounds of technology by creating innovative tools to assist in cleaning up harmful waste faster, cheaper, and more effectively.

The SRP emphasis on research translation moves the Program beyond the essential publication of world-class science in high impact journals to promoting public health program collaborations. Strong working relationships with practitioners at the EPA, ATSDR, state environmental and health departments, and international organizations expedite research translation and achieve real-world public health impacts.

Furthermore, the SRP embraces the goals of Environmental Justice. Our EJ work ranges from addressing vulnerable and minority populations in major U.S. cities to rural populations, including Native American communities and populations in Puerto Rico.

I hope you enjoy perusing this collection of ideas and insights from SRP grantees and program partners. Although the diverse examples included here are not all encompassing, they provide a flavor of the Program and its impact.

Bill Suk, Director, Superfund Research Program

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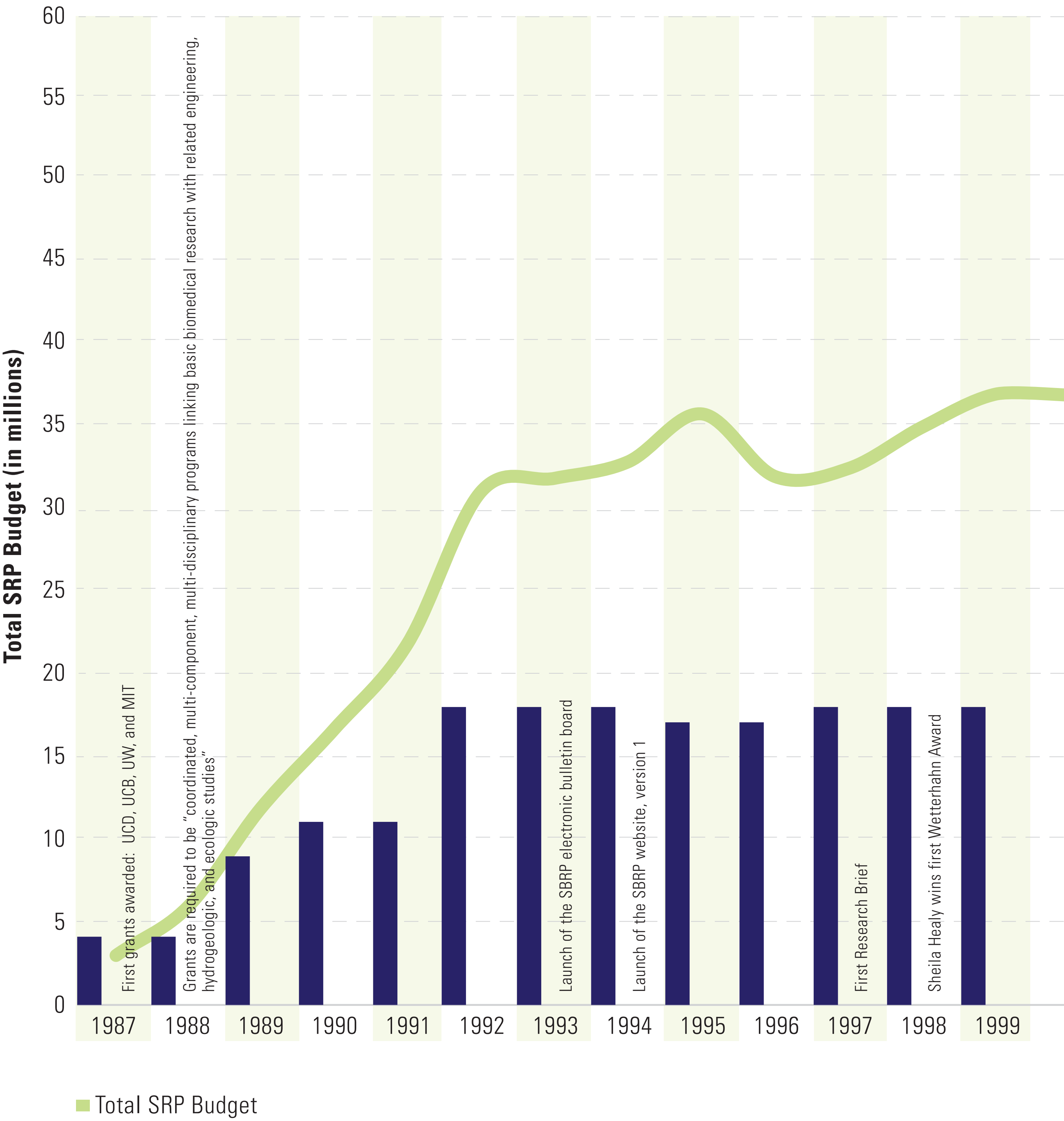
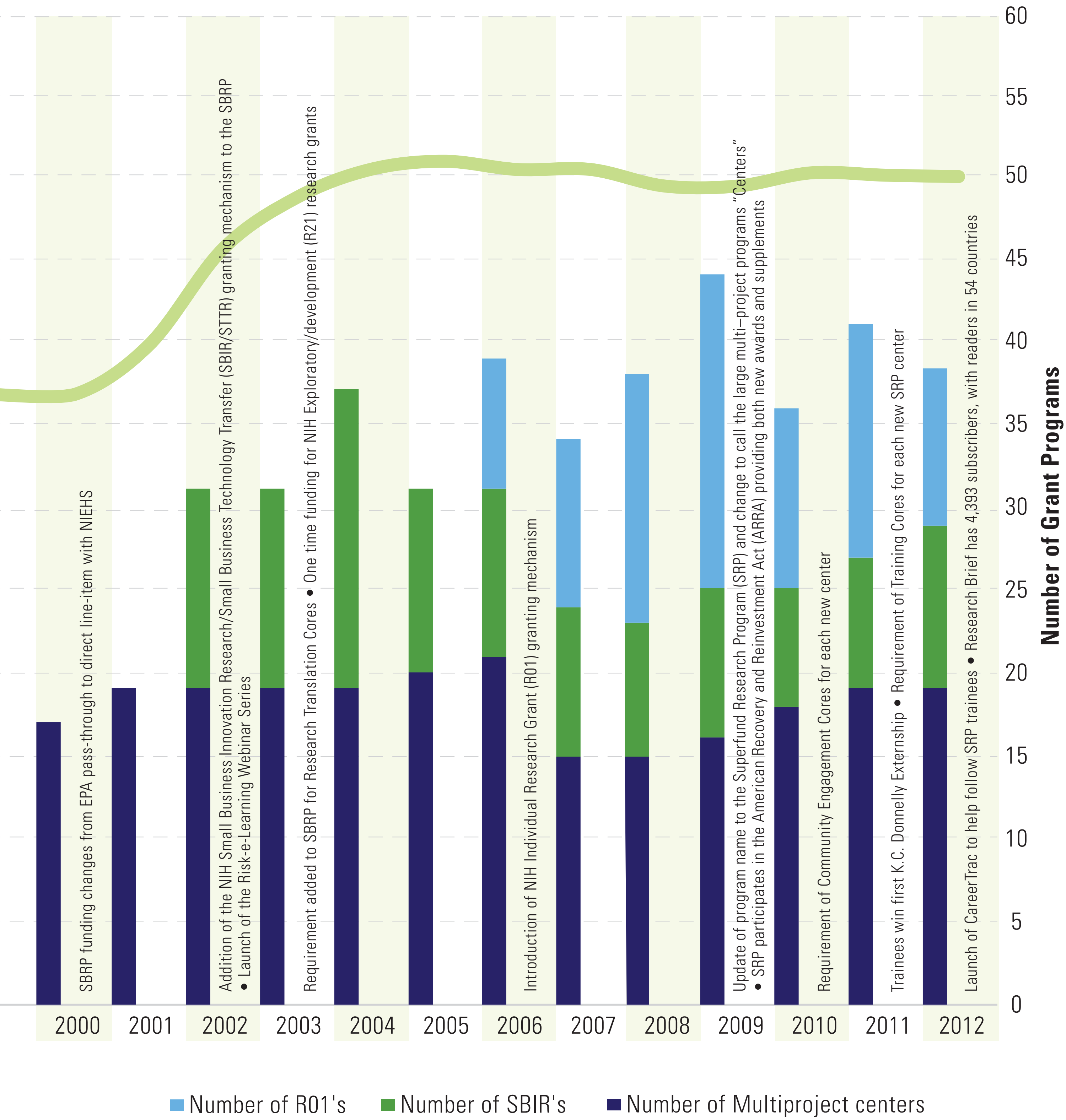
SRP in Review

Innovation and advancing the field of environmental research and science are hallmarks of the Superfund Research Program. Part 1 of this booklet offers a review of how the program has grown and its outputs and accomplishments. The SRP translates grantee's scientific accomplishments to many stakeholders, and a summary of the stakeholder's point-of-view about this translation effort is included. The SRP has always promoted scientific communication and engagement, and a few of many conferences that fostered collaboration among stakeholders are given prominence.

Looking Back: 25 Years of the SRP

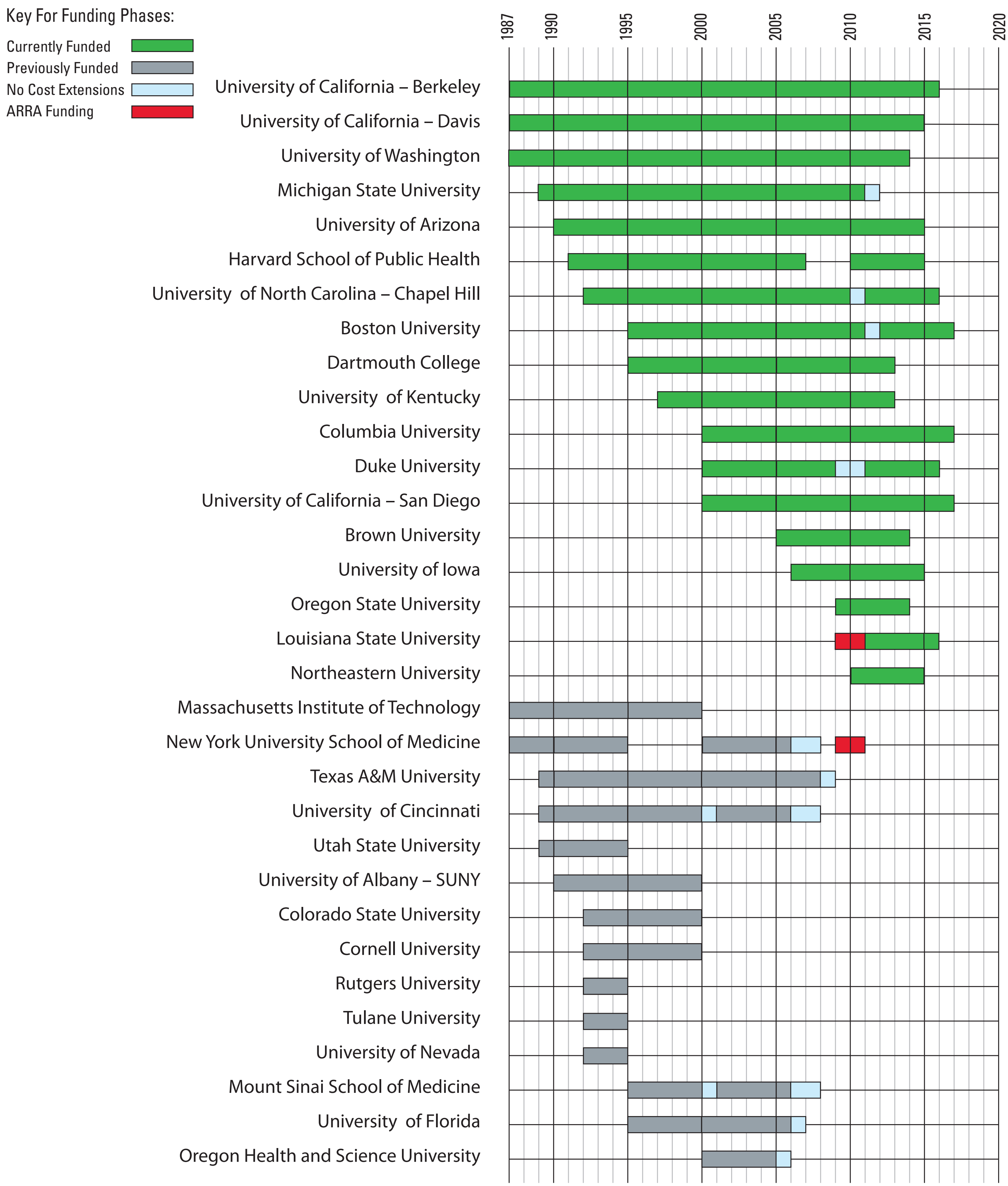
In 1986, the Superfund Amendment Reauthorization Act (SARA) passes, creating the Superfund Hazardous Substance Research and Training Program





SBRP funding changes from EPA pass-through to direct line-item with NIEHS
Addition of the NIH Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) granting mechanism to the SBRP • Launch of the Risk-e-Learning Webinar Series
Requirement added to SBRP for Research Translation Cores • One time funding for NIH Exploratory/development (R21) research grants
Introduction of NIH Individual Research Grant (R01) granting mechanism
Update of program name to the Superfund Research Program (SRP) and change to call the large multi–project programs "Centers" • SRP participates in the American Recovery and Reinvestment Act (ARRA) providing both new awards and supplements
Requirement of Community Engagement Cores for each new center
Trainees win first K.C. Donnelly Externship • Requirement of Training Cores for each new SRP center
Launch of CareerTrac to help follow SRP trainees • Research Brief has 4,393 subscribers, with readers in 54 countries
Number of Grant Programs
0
5
10
15
20
25
30
35
40
45
50
55
60
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Number of R01's
Number of SBIR's
Number of Multiproject centers

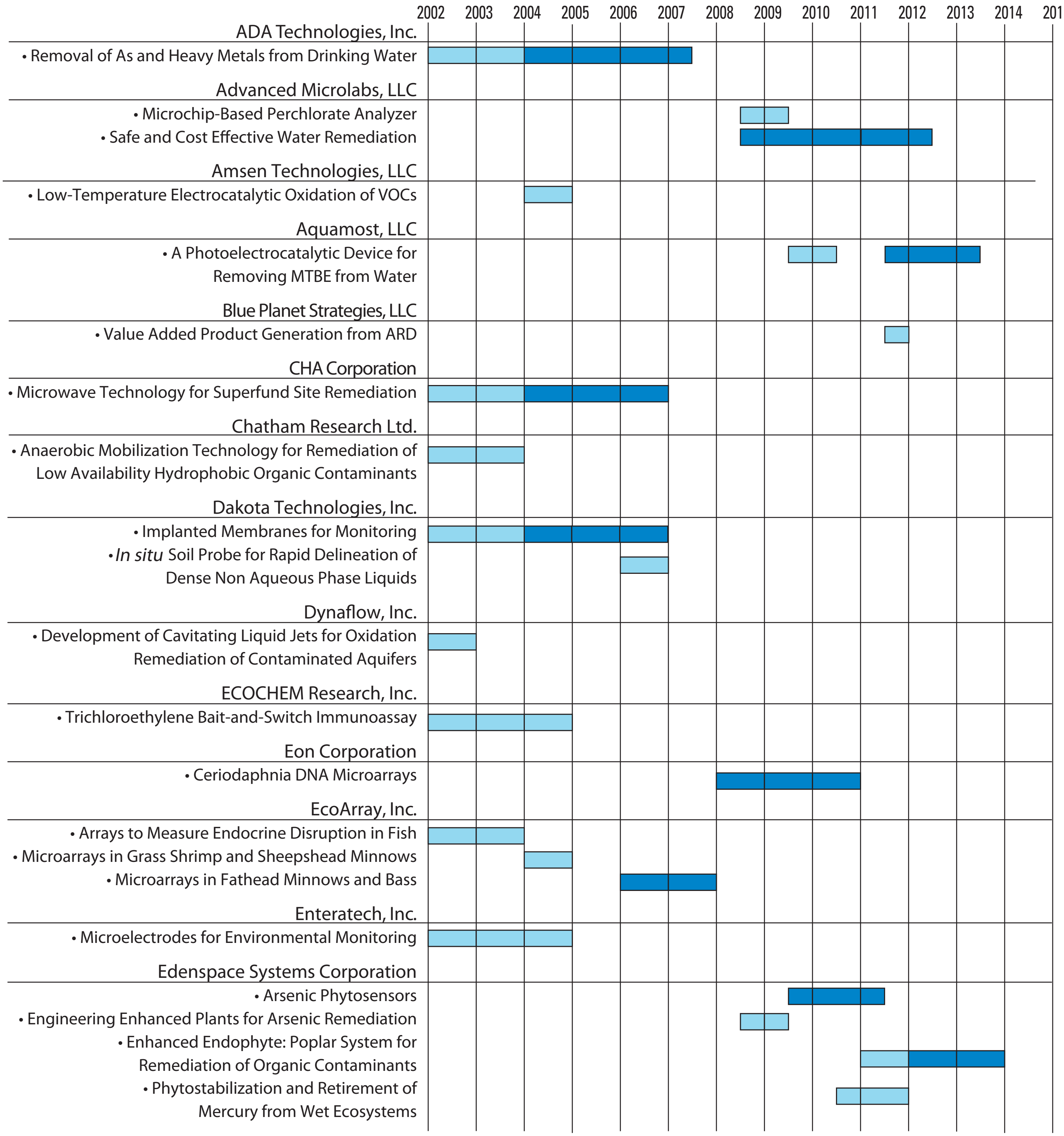
SRP Grantee Funding History
Multi-project Grants (P42)



SRP Grantee Funding History

Small Business Innovative Research (SBIR)

Key for Funding Phases
- Funding Phase I =
- Funding Phase 2=

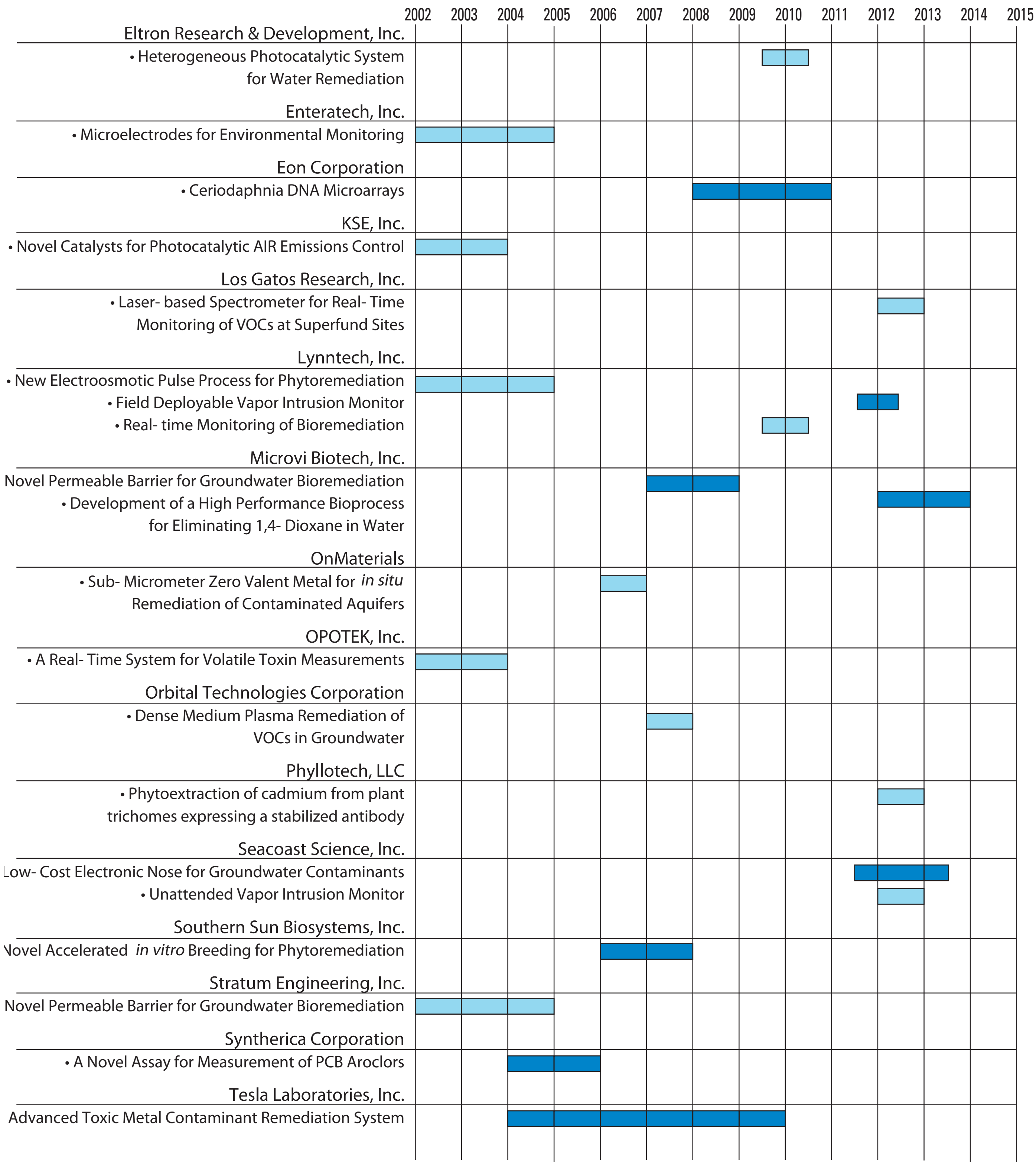


SRP Grantee Funding History *(continued)*

Small Business Innovative Research (SBIR)

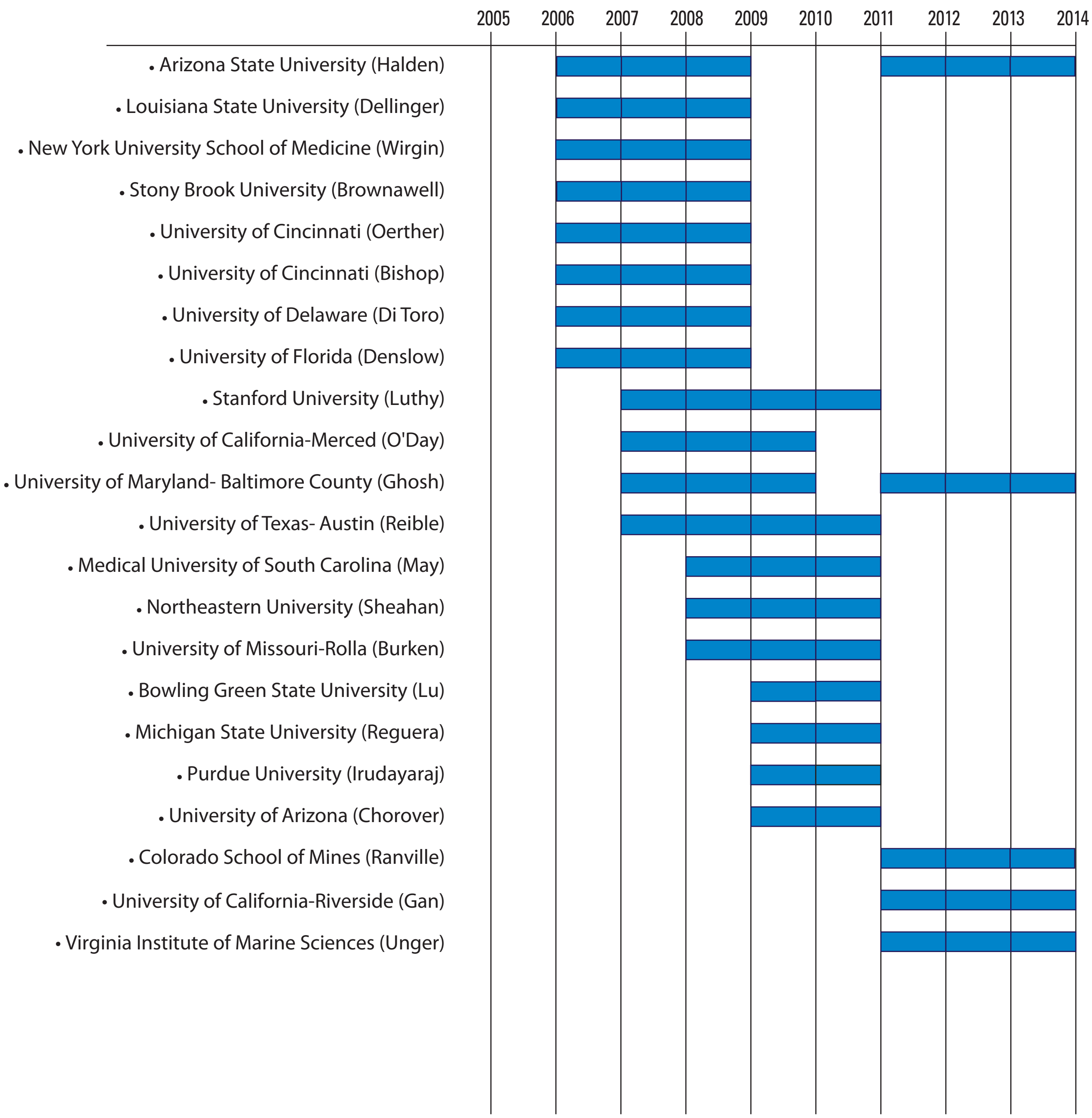
Key for Funding Phases

- Funding Phase I =
- Funding Phase 2=



SRP Grantee Funding History

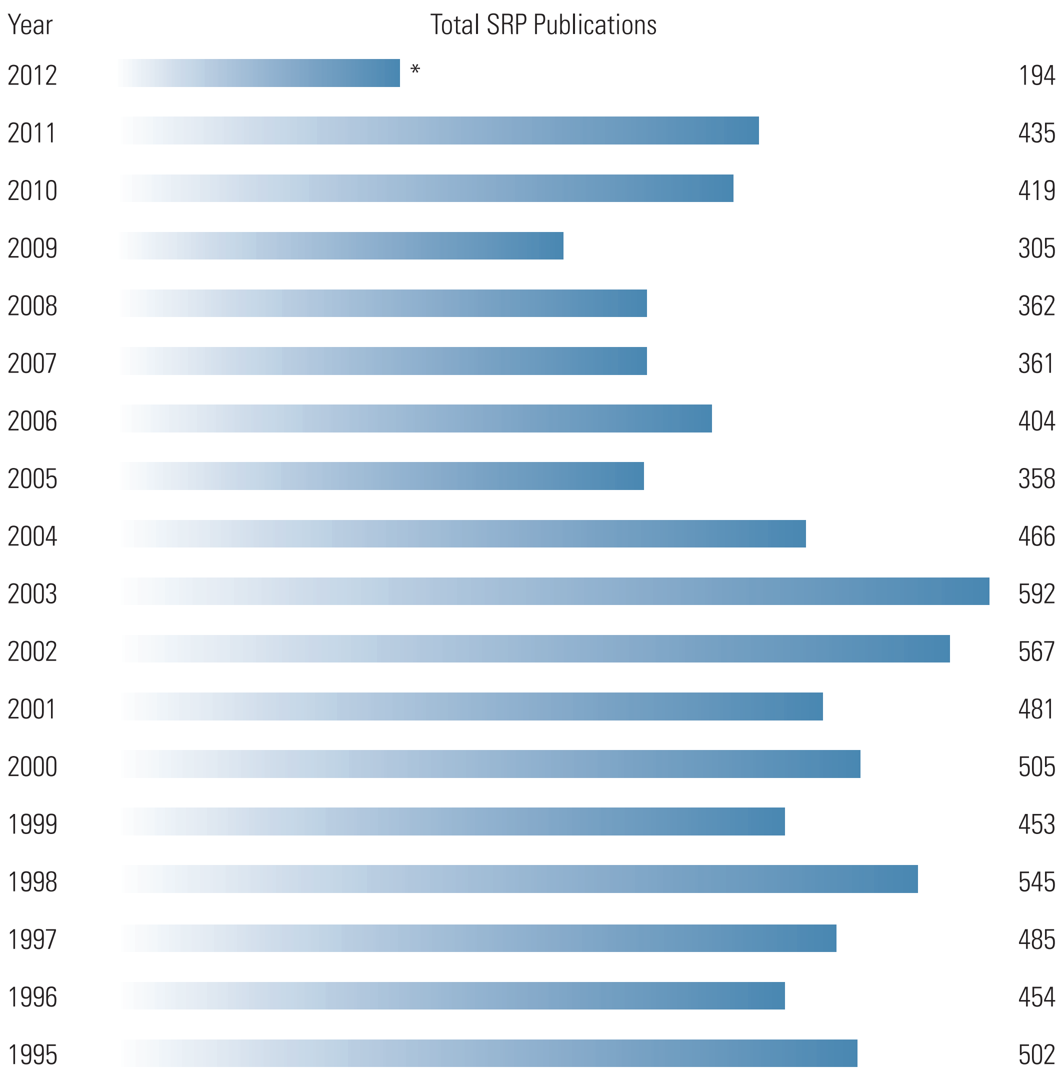
Individual Research Project Grants (R01)



Grantee Publications by the Numbers

Communication of scientific findings is a critical component of research. As shown below, SRP-funded researchers generated an average of more than 450 peer-reviewed publications per year. In keeping with the multidisciplinary nature of the program, the next graphic shows that SRP scientists published in journals targeting a wide range of scientific disciplines. These journals include the areas of environmental health and science, toxicology, biomedical research, microbiology, chemistry, ecology, and engineering.

Number of SRP Journal Articles by Year



The average number of publications per year is 453. Total publications for 1995-2011 are 7,694.

* Information for 2012 is incomplete and not included in the average calculation.

SRP Research by Top Journals

Journal	Number of Published Articles (1995-2012)
Environmental Health Perspectives	390
Environmental Science & Technology	355
Toxicological Sciences	238
Toxicology and Applied Pharmacology	202
Environmental Toxicology and Chemistry	125
The Toxicologist	106
Chemical Research in Toxicology	103
Applied and Environmental Microbiology	102
Carcinogenesis	80
Water Resources Research	58

SRP Research Outputs, 1995-2011

Research Output	Total Count
Publications	7,694
Patents	85

Top 20 Most Cited Journal Articles of SRP Research

The metric Times Cited—the number of times an article has been cited by other articles—is used as a measure of the scientific impact and influence of a paper. Keep in mind that older papers are usually more cited, which may place newer research at a disadvantage in this measure. The following table provides a snapshot of the top cited papers produced by SRP grantees. SRP citation count data was retrieved from the NIH electronic Scientific Portfolio Assistant (eSPA) database.

Top 20 Most Cited Papers by SRP Researchers

Number of Citations	Institution	Paper
1,422	Texas A&M University	Safe S. Polychlorinated biphenyls (PCBs), dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), and related compounds: environmental and mechanistic considerations which support the development of toxic equivalency factors (TEFs). Crit Rev Toxicol. 1990;21(1):51-88.
1,002	Texas A&M University	Safe SH. Polychlorinated biphenyls (PCBs): environmental impact, biochemical and toxic responses, and implications for risk assessment. Crit Rev Toxicol.1994;24(2):87-149.
1,001	Michigan State University	Zhou J, Bruns MA, Tiedje JM. DNA recovery from soils of diverse composition. Appl Environ Microbiol. 1996 Feb;62(2):316-22.
882	University of California, San Diego	Greten FR, Eckmann L, Greten TF, Park JM, Li ZW, Egan LJ, Kagnoff MF, Karin M. IKKbeta links inflammation and tumorigenesis in a mouse model ofcolitis-associated cancer. Cell. 2004 Aug 6;118(3):285-96.
860	University of California, San Diego	Bonizzi G, Karin M. The two NF-kappaB activation pathways and their role in innate and adaptive immunity. Trends Immunol. 2004 Jun;25(6):280-8.
666	University of California, San Diego	Kamata H, Honda S, Maeda S, Chang L, Hirata H, Karin M. Reactive oxygen species promote TNFalpha-induced death and sustained JNK activation by inhibiting MAP kinase phosphatases. Cell. 2005 Mar 11;120(5):649-61.
640	Michigan State University	Cole JR, Wang Q, Cardenas E, Fish J, Chai B, Farris RJ, Kulam-Syed-Mohideen AS, McGarrell DM, Marsh T, Garrity GM, Tiedje JM. The Ribosomal Database Project: improved alignments and new tools for rRNA analysis. Nucleic Acids Res. 2009 Jan;37(Database issue):D141-5
495	University of California, Davis	Denison MS, Nagy SR. Activation of the aryl hydrocarbon receptor by structurally diverse exogenous and endogenous chemicals. Annu Rev Pharmacol Toxicol. 2003;43:309-34
481	University of California, Berkeley	Smith AH, Lingas EO, Rahman M. Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. Bull World Health Organ. 2000;78(9):1093-103.

479	University of California, Berkeley	Smith AH, Hopenhayn-Rich C, Bates MN, Goeden HM, Hertz-Picciotto I, Duggan HM, Wood R, Kosnett MJ, Smith MT. Cancer risks from arsenic in drinking water. Environ Health Perspect. 1992 Jul;97:259-67.
467	Boston University	Waxman DJ. P450 gene induction by structurally diverse xenochemicals: central role of nuclear receptors CAR, PXR, and PPAR. Arch Biochem Biophys. 1999 Sep 1;369(1):11-23.
424	Michigan State	Carter WO, Narayanan PK, Robinson JP. Intracellular hydrogen peroxide and superoxide anion detection in endothelial cells. J Leukoc Biol. 1994 Feb;55(2):253-8.
407	Boston University	Xie W, Radominska-Pandya A, Shi Y, Simon CM, Nelson MC, Ong ES, Waxman DJ, Evans RM. An essential role for nuclear receptors SXR/PXR in detoxification of cholestatic bile acids. Proc Natl Acad Sci U S A. 2001 Mar 13;98(6):3375-80.
361	University of California, San Diego	Maeda S, Kamata H, Luo JL, Leffert H, Karin M. IKKbeta couples hepatocyte death to cytokine-driven compensatory proliferation that promotes chemical hepatocarcinogenesis. Cell. 2005 Jul 1;121(7):977-90.
333	University of California, Berkeley	Dettmer K, Aronov PA, Hammock BD. Mass spectrometry-based metabolomics. Mass Spectrom Rev. 2007 Jan-Feb;26(1):51-78.
321	University of Arizona	Petrick JS, Ayala-Fierro F, Cullen WR, Carter DE, Vasken Aposhian H. Monomethylarsonous acid (MMA(III)) is more toxic than arsenite in Chang human hepatocytes. Toxicol Appl Pharmacol. 2000 Mar 1;163(2):203-7.
307	University of California, Berkeley	Smith AH, Goycolea M, Haque R, Biggs ML. Marked increase in bladder and lung cancer mortality in a region of Northern Chile due to arsenic in drinking water. Am J Epidemiol. 1998 Apr 1;147(7):660-9.
306	Mount Sinai School of Medicine	Grandjean P, Landrigan PJ. Developmental neurotoxicity of industrial chemicals. Lancet. 2006 Dec 16;368(9553):2167-78.
292	University of California, San Diego	Park JM, Greten FR, Li ZW, Karin M. Macrophage apoptosis by anthrax lethal factor through p38 MAP kinase inhibition. Science. 2002 Sep 20;297(5589):2048-51.
274	University of California, Davis	Nguyen DV, Rocke DM. Tumor classification by partial least squares using microarray gene expression data. Bioinformatics. 2002 Jan;18(1):39-50.

Reviewing the Role of the SRP and its Relationship with Stakeholders

Since its inception in 1987, the SRP has applied a multidisciplinary research approach to provide a solid foundation which environmental managers and risk assessors can use for sound decision-making related to Superfund and other hazardous waste sites. Research plays a crucial role in addressing challenges posed by environmental contamination such as health risks, toxicity, exposure predictions, fate and transport, and the need for cost-effective treatment of hazardous waste sites found throughout the United States. Accordingly, the SRP is committed to bridging the link between Program science and its stakeholders.

In order to get a feel of how effective our efforts have been over the years, we approached a few stakeholders to collect their perspectives on our efforts. We learned what they consider to be the biggest successes of the SRP and heard suggestions for moving forward. Our discussions included a mix of EPA Superfund Technology Liaisons (STLs), EPA Remedial Project Managers (RPMs), researchers in the EPA Office of Research and Development, EPA risk assessors and toxicologists, and colleagues at the ATSDR and NIEHS.

Getting to know the SRP

Many of the stakeholders stated their initial contact with the SRP came though meeting and outreach efforts led by Beth Anderson, SRP Program Analyst at NIEHS. Others noted that they learned about the SRP through grantee outreach efforts at Superfund Sites. Much to our delight, a few stakeholders commented how they know the SRP first hand as they were funded by the SRP in graduate school and later went on to work for the EPA. Now they continue their relationship with the Program as a stakeholder.

"There was a time when the EPA and the SRP barely knew each other. Now, you folks go to our conferences, we go to your conferences, and we organize multiple activities together. The change has been really good."

–Mike Gill, EPA Region 9 STL

"My experience with the SRP is that it facilitates interactions between me and investigators who are also interested in similar areas but don't have the same particular expertise."

–Geniece Lehmann, Ph.D., EPA IRIS Chemical Manager

SRP and Stakeholder Goals

Most of the individuals interviewed feel that SRP goals align with their professional/career goals. In particular, risk assessors felt that SRP goals align extremely well with managing risk because of the health effects research side as well as the non-biomedical remediation efforts. Stakeholders recognize the need for innovative research done by the SRP and its value in risk assessments. RPMs expressed their continuing interest for more short-term applied remediation projects. They've appreciated increasing efforts by the SRP in the recent years to balance longer-term research with an eye toward short-term applicability.

Interactions between SRP and Other Agencies

Overall, stakeholders feel that the interactions between SRP and the EPA or ATSDR are beneficial. Several individuals highlighted seminars, conferences, and relevancy reviews as ways that they have been able to collaborate with the SRP. They also mentioned the research briefs and Risk e Learning seminars as a way to stay updated on SRP research being performed. Stakeholders emphasized the value of Research to Risk Assessment (R2RA), an interagency working group established to promote the use of cutting-edge science to further assist and advance the assessment of environmental risks at hazardous waste sites in a cost-effective manner. Stakeholders explained that R2RA is a great outlet to create partnerships and inform the SRP of the research needs to improve assessment and remediation at Superfund sites.

"SRP gives us a better idea of the state of the science and what we should expect to come out in the near future and the potential impact it may have on an ongoing assessment."

–Xabier Arzuaga, Ph.D., EPA IRIS risk assessor

It was also clear that many stakeholders believe that there is much more outreach and collaboration now than in the early years of the Program. General consensus showed that SRP has become more responsive to the EPA program needs over time. There has also been more coordination and information exchange with RPMs and more coordination at ATSDR. Stakeholders feel that the SRP has enhanced is efforts in communicating research findings and their ability to access these findings.

SRP Successes

"We continue to identify gaps in our understanding of environmental science, so we need mechanisms for filling those gaps. The program has been doing a good job of assisting us."

-Mark Maddaloni, DrPH, DABT, EPA Region 2 Senior Toxicologist

"It is important for our institute to be able to show that our research makes a difference, and this Program in particular absolutely makes a difference. That is the beauty of the SRP."

-Shiela Newton, PhD., NIEHS Office of Policy, Planning, and Evaluation Director

Stakeholders generally agreed that the collaboration and outreach efforts by the SRP have been a huge success. This includes collaboration with local communities at Superfund sites as well as activities to engage stakeholders in their research, such as conferences and webinars. They have been successful in translating their research into real world applications and reaching out to where it is useful.

The multidisciplinary nature of the SRP has also led to many of its research successes. Stakeholders emphasized that a major strength of the SRP is its ability to address an issue from the biochemical aspect, engineering aspect, and community aspect. Furthermore, several specific successes mentioned involved the application of SRP research at a Superfund site.

"SRP does fantastic work! What is particularly important is finding the areas of overlap between the research focus of the various SRP Centers, the EPA, and the technical assistance needs of impacted communities."

- Bob Shewack, EPA Region 1 TAG Grant Program Coordinator

Moving Forward

Stakeholders were also asked how the SRP can improve as it moves forward. Several stakeholders emphasized their appreciation for conferences and webinars on specific topics of critical interest to them. They would like to see more of these forums on wide range of topics relevant to RPMs and other stakeholders. Some also mentioned that they would like more initiatives like the R2RA, where we are considering big topic areas rather than focusing on regional needs. By moving toward more initiatives like R2RA, the SRP can be better positioned to tackle the key issues of interest to other agencies and to efficiently address major concerns at Superfund and other hazardous waste sites around the country.

Fostering Collaboration through Innovative Conferences

Over the years, the SRP has sponsored over 200 conferences, bringing together scientists to discuss important scientific topics. The conferences have covered new and innovative approaches to science and raised awareness of emerging issues in the field of human health and the environment. By encouraging collaboration and exploring new scientific topics, SRP-sponsored conferences have promoted the multidisciplinary nature of the SRP and established new areas of research to scientific problems. A few examples of timely SRP-sponsored conferences which have spawned significant growth of a field are highlighted below:

In 1990, SRP, taking a leadership role in the field, sponsored "Application of Molecular Biomarkers in Epidemiology," which provided an up-to-date review of molecular biomarkers to promote discussion between laboratory scientists and epidemiologists on the utility of the biomarkers. The conference addressed the communication gaps that existed between epidemiologists and laboratory scientists and helped launch the field of molecular epidemiology.

In 1993, SRP hosted the "Pediatric Environmental Research Workshop" to explore children's environmental health research and raise awareness of the need to understand the effect of environmental exposures on children. This was the first conference at NIEHS to focus specifically on children's environmental health issues, which has since expanded to a major area of study for NIEHS.

Also in 1993, SRP supported the "Napa Conference on Genetic and Molecular Ecotoxicology" to highlight new opportunities to improve the impact of genetic and molecular toxicology to investigate sublethal effects on the ecosystem from exposure to hazardous substances. Participants emphasized integration of genetic ecotoxicology, ecological genetics, and molecular biology and how they should be directed toward improving our understanding of the ecological implications of genotoxic responses. This conference was the first of its kind to improve the utility of genetic and molecular ecotoxicology.

At another timely conference, in 2010 the SRP hosted "Health Consequences from Xenobiotic – Gut Microbiome – Host Interactions," which was the first NIEHS conference on the microbiome. An interdisciplinary group of scientists gathered at NIEHS to review the growing body of literature on the microbiome, which are the microbial communities inhabiting the human body. Since this conference, NIEHS has actively pursued additional work on understanding the role of the microbiome in the disease-exposure paradigm.

SRP Awards

Since its inception, the SRP has had a robust interdisciplinary training program. We consider training the next generation of environmental scientists and public health researchers to be a crown jewel of the program. To highlight the importance of trainees, the SRP offers two award opportunities for graduate students and postdoctoral researchers who are affiliated with its grantees.

Established in 1998, the Karen Wetterhahn Memorial Award recognizes an outstanding young research scientist who demonstrates the qualities of scientific excellence exhibited by Wetterhahn. Now in its third year, the KC Donnelly Externship Award provides an opportunity for current SRP-funded graduate students and postdoctoral researchers to compete for translational and/or trans-disciplinary externships outside of their university.

Karen Wetterhahn Memorial Award

Karen E. Wetterhahn (1948-1997) had an international reputation as a research chemist. An expert in the mechanisms of metal toxicity, she was best known for her research on chromium. A professor of chemistry at Dartmouth College, she founded Dartmouth's Toxic Metals Research Program in 1995, after receiving a $7 million grant from NIEHS to study how toxic heavy metals affect the human body.

Tragically, she became ill and died in 1997, as a result of a laboratory accident involving a highly toxic mercury compound. A few drops of the colorless compound had penetrated her protective latex glove. After becoming ill, blood tests showed that her level of mercury was 80 times the threshold of toxicity. Despite intense chelation therapy, she died six months after exposure.

Product tests later showed that dimethylmercury—the chemical Wetterhahn was using as a reference in her work with cadmium—can rapidly permeate latex gloves and enter the skin within 15 seconds. Wetterhahn's death shocked the scientific community, including regulatory agencies, because she had taken all required safety measures known at the time. An intense investigation ensued to discover how standard safety precautions had failed. Safety guidelines by the Occupational Safety and Health Administration were soon changed to reflect the huge risk associated with the use of dimethylmercury.

In addition to research, Wetterhahn was passionate about teaching and getting students excited about science. Concerned about the higher rate of dropout from the sciences among undergraduate women compared to men, Wetterhahn worked with a colleague to develop the Women in Science Project at Dartmouth. This successful program provides a learning environment where first-year women engage in experiences designed to further their interest in science, math, or engineering.

As a tribute to her legacy, NIEHS created the annual Karen Wetterhahn Memorial Award shortly after her death. Nominations for the award come from scientists directing projects funded by the SRP. The award recognizes outstanding young scientists who are conducting research relevant to Superfund or the cleanup of hazardous waste sites. The awardee receives support to attend the Superfund Research Program Annual Meeting to present his or her research. The recipient also receives support to visit NIEHS and to attend one major scientific conference.

Awardees

2012 – Nicki Baker, University of Kentucky

Baker was recognized for her work on how environmental toxins, namely co-planar PCBs, impact obesity and type 2 diabetes. Baker is currently a doctoral student mentored by Lisa Cassis, Ph.D., in the Graduate Center for Nutritional Sciences at the University of Kentucky. Through her dissertation project, her results imply that exposure to PCBs may blunt the beneficial effects of weight loss to prevent insulin resistance and type 2 diabetes, and that dietary polyphenol and resveratrol may protect against PCB-induced impairment of glucose homeostasis.

2011 – Monica Ramirez-Andreotta, University of Arizona

Ramirez-Andreotta won the award based on her Gardenroots project, a citizen-science program in which she worked to educate and empower people who had home gardens and lived near sites contaminated from smelter and mining operations. This project also collected home-grown vegetables, soil, and water samples for chemical analysis. Currently a Ph.D. candidate in Soil, Water and Environmental Science at the University of Arizona, she is focusing on integrating the fundamentals of environmental science, human exposure assessment, and methods to positively harness community knowledge and activism.

2010 – Courtney Horvath, Dartmouth College

Horvath's award highlighted her contributions to research on effects of low dose arsenic exposure on the immune system. Her research demonstrated that low-level arsenic exposure in mice significantly impaired the immune response in the lung. After completion of her Ph.D., she worked as a postdoctoral fellow at Dartmouth Medical School. Horvath is currently a Scientist at Genzyme, a Sanofi company, where she leads nonclinical toxicology efforts on a variety of programs.

2009 – Karrie Radloff, Columbia University

Radloff was acknowledged for her work on arsenic fate and transport in Bangladesh, specifically investigating how arsenic mobility restricted viable drinking water options in rural areas. After completing postdoctoral research at the Lamont-Doherty Earth Observatory, she is now an Environmental Engineer specializing in contaminant fate and transport and groundwater hydrology at Gradient in Boston.

2008 – Laura Senier, Brown University

Senier was recognized for the work she did through Brown's Community Outreach Core, providing leadership development support to environmental justice communities throughout Rhode Island. Now an Assistant Professor in community and environmental sociology, she holds a joint appointment in the Department of Community and Environmental Sociology and the Department of Family Medicine at the University of Wisconsin. Her research interests include the sociology of public health and medicine, community environmental health, and environmental justice.

2007 – Roxanne Karimi, Dartmouth College

Karimi won the award based on her outstanding contributions to metals research, specifically the accumulation and cycling of heavy metals within freshwater organisms, food webs, and ecosystems. She is now a postdoctoral fellow working in environmental health, freshwater and marine pollutants, ecological stoichiometry, and physiological ecology at the School of Marine and Atmospheric Sciences at Stony Brook University. Her recent research examines levels of contaminants (mercury) and nutrients (omega-3 fatty acids) in seafood species, in human exposure from seafood consumption, and associations with health factors, including autoantibody concentrations.

2006 – Alicia R. Timme-Laragy, Duke University

Timme-Laragy's research used a zebrafish embryo model to understand how certain combinations of PAH greatly increase toxicity over what is predicted from studies of single PAH. This research was noted for elucidating mechanisms underlying the very marked, and surprising, synergy that had been previously observed between PAHs that act as AHR (aryl hydrocarbon receptor) agonists and PAHs that act as CYP1A (cytochrome P450 1A) inhibitors on cardiovascular development in zebrafish embryos. She is now a postdoctoral scholar at the Woods Hole Oceanographic Institution where she studies oxidative stress and antioxidant defenses during embryonic development using the zebrafish model.

2005 – Tiffany Bredfeldt, University of Arizona

Bredfeldt conducted research on the carcinogenicity of arsenic metabolites and their underlying mechanisms of action. Her observations were noted as strongly supporting the concept that arsenic metabolites may function as the ultimate toxicants in arsenic-induced pathologies due to their heightened toxicity compared with inorganic arsenic. In her current position as a Senior Toxicologist at the Texas Commission on Environmental Quality, Bredfeldt focuses on human health risk assessment, generation of toxicity factors, and NexGen risk assessment approaches.

2004 – Anne Spuches, Dartmouth College

Spuches won the award while a postdoctoral fellow at Dartmouth College, where she used Isothermal Titration Calorimetry to quantify the interaction of arsenite and monomethylarsenite with various thiols. Spuches is now Assistant Professor in Bioinorganic Chemistry at East Carolina University. Her research focuses on how metals (both toxic and essential) are "trafficked" within the cell with the goal to understand how metals are regulated within the intra-cellular milieu.

2003 – Monica Mendez, University of Arizona

Mendez earned the award based on her investigations of the microbial-plant interactions that accompany successful establishment of vegetation in harsh environments. In 2007, Mendez graduated with a Ph.D. from the Soil, Water, and Environmental Program at the University of Arizona. She is now Assistant Professor of Environmental Biology, Department of Biology and Chemistry, at Texas A & M International University in Laredo, Texas.

2002 – Elena Craft, Duke University

Craft was acknowledged for her research examining the characterization of metal responsive signal transduction pathways and the determination of the precise mechanism by which metals activate metal-responsive transcriptions factors. She completed her Ph.D. in 2006 while conducting research at the NIEHS Laboratory of Molecular Toxicology. Next, as an environmental consultant with ChemRisk, she contributed to litigation support for toxic tort cases, and the summarization of toxicity and exposure information for a variety of chemicals. In 2008, Craft joined the Environmental Defense Fund office in Austin, Texas where her area of expertise is air toxics issues, focusing on reducing greenhouse gas emissions from the energy and transportation sectors. Her efforts have led to the creation of clean truck programs in the southeast. She advocates for policies that increase energy efficiency, reduce exposure to air toxics, and improve human health. Recently, she was appointed to a two-year term on EPA's Science Advisory Board Environmental Justice Technical Review Panel.

2001 – Blakely M. Adair, Texas Tech University

Adair studied metal contaminant mixtures found on the Anaconda Smelter Superfund site in Montana for her doctoral research. She examined metal uptake, distribution, and toxicity in small birds, and her findings were used in conjunction with other small animal data to prioritize remediation processes on the Superfund site. From 2002-2009, Adair completed post-doctoral experiences at the Environmental Protection Agency and the National Institute of Standards and Technology. She is currently an assistant professor in analytical chemistry and environmental toxicology at The Citadel, where her research focuses on techniques for quantification of biologically and environmentally relevant metals and metalloids in representative matrices at relevant concentrations, and the application of element specific detection of heteroatoms or elemental tags to produce more accurate biomolecule quantification methods.

2000 – Angeline Andrew, Dartmouth College

Andrew focused on the underlying cellular, biochemical, and molecular processes leading to lung diseases associated with nickel exposure in her graduate research. In 2005, she received an NCI K07 career development grant to study how genetic and environmental factors interact to impact bladder cancer prognosis. She is currently a research assistant professor in the Community and Family Medicine Department at the Geisel School of Medicine at Dartmouth specializing in molecular epidemiology, with research interests in genetic and environmental factor interactions and their impact on cancer risk or prognosis. The ultimate goal of her research is to develop profiles of molecular diagnostic markers and patient characteristics that can be used to target optimal therapeutic approaches for specific groups of patients.

1999 – Elisabeth Harrahy, Colorado State University

Harrahy won the award based on research in the development and application of molecular genetic approaches for assessing the effects of heavy metals at Superfund sites, which provided insight into the mechanisms of heavy metal toxicity. She completed a post-doctoral project funded by the U.S. Fish and Wildlife Service that involved assessing the reliability of 30 years of toxicity data collected by the U.S. Department of Agriculture on the effects of the avicide DRC-1339 on non-target bird species. Later, as an environmental toxicologist with the Wisconsin Department of Natural Resources, she was principal investigator on an EPA-funded project to examine the sources, toxicity, and estrogenic activity of polybrominated diphenyl ether flame retardants. Currently, Dr. Harrahy is an assistant professor in the Department of Biological Sciences at the University of Wisconsin - Whitewater. Her research interests include blue-green algal toxins, and the effects of pesticides and pharmaceuticals on aquatic organisms.

1998 – Sheila Healy, University of Arizona

Healy, the first Karen Wetterhahn Memorial Award winner, won for her metals research using guinea pigs that presented important findings concerning the primary method of arsenic detoxification in mammals. As a postdoctoral fellow in the Department of Neurology at the University of California, San Francisco, she studied the molecular and structural requirements for the conversion of cellular prion protein to its pathogenic form, the agent that causes Bovine Spongiform Encephalopathy (BSE) or mad cow disease. Next, Healy was a science fellow at the Center for International Security and Cooperation at Stanford University (2004-2005) where she analyzed USDA policy addressing BSE. Healy then worked as a toxicologist for a small preclinical CRO in northern California where her work supported IND applications as well as research and development. Since 2008, Healy has worked as a toxicologist with the EPA.

KC Donnelly Externship Award

Kirby Cornwall (KC) Donnelly (1951-2009), a career-long Aggie, was a professor and head of the Department of Environmental and Occupational Health in the Health Science Center as well as Associate Director of the SRP at Texas A&M University. Donnelly also received a B.S. in microbiology and a Ph.D. in toxicology from Texas A&M University.

Donnelly's studies on environmental exposures, animal and human population studies, and genotoxicity of complex chemical mixtures changed the way environmental health is perceived. Spanning the world, his research locations ranged from China to Eastern Europe to numerous areas in the U.S. including close-to-home South Texas.

"He was an idea man who finished the tasks at hand," according to a memorandum by Nancy Dickey, president of the Texas A&M Health Science Center.

Donnelly's contributions to the SRP were numerous, but two areas of commitment stand out: active promotion of partnerships and dedication to his students. His relationships with EPA scientists and remedial project managers not only increased the relevance of his research but supported EPA's efforts. He initiated and championed the SRP Bioassay Network, bringing together many researchers and scientists. Donnelly always engaged students in his research activities, including his work with EPA and the SRP Bioassay Network.

Additional research efforts by Donnelly included collaboration with the CDC and the EPA to conduct a study on pesticide exposure in children residing in four rural communities and studies using health education as an intervention to reduce childhood exposure to pesticides in Texas colonias (rural, unincorporated border communities). As an integral part of the South Texas Environmental Education and Research (STEER) program, he helped bridge the gap between public health and medicine for more than 500 students from distinguished health professions training programs across the nation. A leader of environmental research on the U.S. – Mexico border, Donnelly stressed the importance of service coupled with learning and community-based research as he worked to improve the lives of colonia residents. The KC Donnelly STEER Scholarship Fund at Texas A&M University was established in his honor.

Also in his honor, the NIEHS SRP established the KC Donnelly Externship Award, an administrative supplement to provide current SRP-funded graduate students and postdoctoral researchers with translational and/or trans-disciplinary opportunities and experiences with other SRP-funded centers, government laboratories, or other federal, state, or Tribal agencies.

2012 Winners

Steven O'Connell, Oregon State University

The externship provided O'Connell an opportunity to conduct studies using passive sampling devices to measure bioavailable contaminants in water and sediment at the Lower Duwamish Waterway Superfund Site. Kira Lynch, Superfund Technology Liaison in EPA Region 10, provided mentorship and guidance for his research. "Specifically, this opportunity will allow me to see how state, federal, and local parties collaborate with an ongoing Superfund remediation strategy, and how the bioavailable data I will provide might contribute," said O'Connell.

Vanessa De La Rosa, University of California, Berkeley

Under the guidance of James Swenberg, D.V.M. and Jun Nakamura, Ph.D., D.V.M. at the University of North Carolina at Chapel Hill, De La Rosa studied trichlorethylene's metabolite DCVC and its mechanisms mediating TCE-induced renal cancer. The externship provided her an opportunity to use the avian DT40 cell line to see how DNA damage and repair mediates toxicity and cancer of the superfund contaminant trichloroethylene. "This work will supplement previous studies conducted in other organisms to identify conserved mechanisms of trichloroethylene toxicity," said De La Rosa.

Sabine Vorrink, University of Iowa

During her externship at the University of Arizona under the guidance of Bernard Futscher, Ph.D., Vorrink conducted mechanistic studies of the effects of polychlorinated bi-phenyls (PCBs) on the aryl hydrocarbon receptor (AhR) and hypoxia inducible factor (HIF1α) and with their aryl hydrocarbon receptor nuclear translocator (ARNT) complexes. "This will extend my experience and scientific knowledge into related toxicology fields and will significantly expand my training horizons," said Vorrink.

2011 Winners

Celys Irizarry, University of Puerto Rico – Mayagüez

Under the guidance of Ingrid Padilla, Ph.D., of the Northeastern University SRP, Irizarry took part in the huge task facing regulatory agencies during her externship. Working at the Caribbean Environmental Protection Division of the EPA and the Puerto Rico Department of Health, she collected water samples and assessed the water quality at 10 Superfund sites on the north coast of Puerto Rico. The agencies used her work to inform water-quality assessment models. "My data and analysis will give them a large picture of the problem and show how the water quality is changing over time," said Irizarry.

Alvine Mehinto, Ph.D., University of Florida

Mehinto worked with Chris Vulpe, Ph.D., at UC Berkeley to find underlying toxicity pathways that are at work in simple organisms such as yeast as well as in higher organisms such as marine life and humans. She used Vulpe's parallel detection analysis technique to find gene changes in a yeast model exposed to the same contaminants. "The externship allowed me to improve my bioinformatics skills. It gave me a different perspective and new tools to consider for my next research proposal," said Mehinto.

Xianai Wu, Ph.D., University of Iowa

Under the direction of Bruce Hammock, Ph.D. at UC Davis, Wu learned novel metabolomic techniques and used them to investigate the effects of PCB126. She was interested in profiling changes in lipids, including lipids known as eicosanoids and lipids derived from polyunsaturated fatty acids. "I learned a technique that employs solid phase extraction and liquid chromatography electrospray ionization tandem mass spectrometry in multiple reaction-monitoring mode," said Wu.

SRP Research Highlights

The research highlights contained in this booklet illustrate that the SRP spans basic to applied research, and to community engagement. Because the program publishes more than 450 articles each year, this booklet can only offer a brief look at the work of SRP researchers. Their work helps improve understanding of many harmful chemicals in diverse areas such as toxicological modes of action, effectiveness of remedial efforts, and best ways to engage communities affected by hazardous substances.

Part 3: SRP Grantee Highlights

Assessing Exposure to Hazardous Chemicals

Researchers Find Arsenic in Common Foods

Dartmouth SRP researchers discovered that rice, as well as organic foods containing brown rice syrup, can contain higher levels of arsenic than the EPA arsenic drinking water standard.

Brian Jackson, Ph.D., and colleagues at the Dartmouth College SRP, identified a previously under-recognized source of arsenic exposure – common foods. They found that organic brown rice syrup, which is used in organic food products as an alternative to high fructose corn syrup, can contain significant concentrations of inorganic arsenic, the form classified as a human carcinogen. Toddler formula, cereal bars, and energy foods aimed at athletes that contained organic brown rice syrup had higher total arsenic concentrations than similar products without the syrup. In a second study, Jackson's research team showed that infant formula and jarred baby foods are a significant source of arsenic exposure.

A third study by Margaret Karagas, Ph.D., and colleagues, also at the Dartmouth SRP, showed rice consumption was associated with increased urinary levels of arsenic in pregnant women. "It's possible that for a large number of individuals, their main exposure route to arsenic is food, not water. But we don't have guidelines on what the acceptable levels are for arsenic in food," said Jackson.

The studies revealed that, in some cases, the amount of total arsenic consumed in certain common foods is as much or more than the acceptable limits set for drinking water by the EPA. In all three studies, the authors concluded that their results point to a need to set regulatory limits for arsenic in food.

Atmospheric Sources of PCB Congeners

Using a novel sampling system developed for this project, a group of researchers at the University of Iowa SRP, led by Keri Hornbuckle, Ph.D., have been collecting and analyzing air samples throughout the city of Chicago since 2008. These field efforts led to the first evidence of the presence of the PCB11 congener in urban air. PCB11 (3,3'-dichlorobiphenyl) was not frequently used in industrial PCB mixtures so its presence in air samples was surprising.

Based on its presence in wastewater from paint manufacturing facilities, the researchers conducted a follow up study in which they analyzed 33 commercial paint pigments for all 209 PCB congeners. They detected more than 50 PCB congeners in the pigments, including PCB11, and identified commercial paint as an important source of atmospheric PCBs. The researchers continue to collaborate with other Iowa SRP researchers to determine whether PCB11 presents a hazard.

Hornbuckle's research group is also measuring PCB concentrations in sediment cores collected from the Indiana Harbor and Ship Canal (IHSC), Lake Michigan. Dredging of the IHSC system began in spring 2012, and it is not clear how the dredging will affect PCB exposures. The researcher's initial investigations suggest PCB concentrations may be much higher in deep sediments than surface sediments. These initial findings indicate that dredging the area could increase the potential for human exposure to PCBs in the region.

Wildlife Biomonitoring at Hazardous Waste Sites

Wildlife provides a practical and sensitive means for determining the biological effectiveness of remediation efforts, according to studies led by Mike Hooper, Ph.D., through the University of Washington SRP. He led a team of researchers that developed biomarkers for birds and mammals to gain data on health-based exposure and effects for wildlife. Hooper monitored these wildlife biomarkers in indigenous wildlife during and after clean-up activities.

Mike Hooper, Ph.D., developed methods to determine levels of contaminants at hazardous waste sites based on biomarkers in wildlife.

The Rocky Mountain Arsenal was the team's largest biomonitoring project. About 10 miles from downtown Denver, the Arsenal was the site of manufacture of chemical warfare agents, incendiary munitions, and pesticides during its 50 years as an active Army installation. Hooper collaborated with the Fish and Wildlife Service in investigating the health of wildlife to monitor the biological effectiveness of the Arsenal site clean-up.

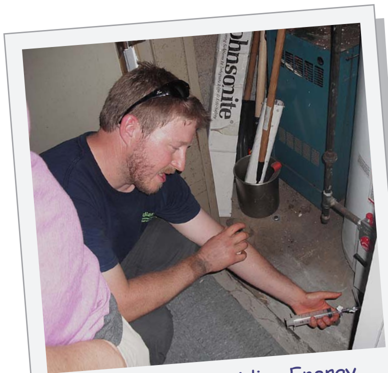
Hooper's results indicated that scientists can use some species to determine whether certain contaminants at hazardous waste sites exist at levels harmful to wildlife. Hooper's findings were successfully introduced into the remediation site assessment of the Rocky Mountain Arsenal. The results of the panel of bioassays and soil contaminant analyses were used to make decisions about site remediation and were incorporated into the site's long-term biomonitoring program. Furthermore, the Fish and Wildlife Service incorporated this approach to site assessment at other sites where the impact of contaminants on wildlife is of potential concern.

Using GIS Data to Identify Children's Exposure Risks

The Children's Environmental Health Initiative (CEHI) at Duke SRP supports a series of environmental research projects emphasizing the special vulnerabilities of children to toxic effects of environmental exposures. Among several ongoing projects, Marie Lynn Miranda, Ph.D., Director of the CEHI, has been leading research projects using geographic information systems (GIS)-based analysis that focus on children's environmental health, particularly reproductive and developmental toxicants and childhood lead exposure.

Recently Miranda's team validated modeling of geocoded data to identify children most at risk for lead exposure. The models are designed to require relatively low levels of effort on geocoding, allowing resource-constrained local health officials and other groups to analyze local data and make informed decisions about how to best focus their efforts in preventing and mitigating lead exposure risks. By applying these types of GIS models, Miranda demonstrated an association between reduced birth weight and levels of PM10 and PM2.5 in air at the county level in North Carolina. The results raise concerns that, despite North Carolina's attainment of federal air quality standards, there remains a negative association between these pollutants and birth weight.

Evaluating Vapor Intrusion Exposures and Risks



Flint Kinkade of Viridian Energy demonstrating the sampling technique with a syringe.

(Image courtesy of Jim Rice)

A Brown University SRP research group led by Eric Suuberg, Ph.D., and Kelly Pennell, Ph.D., headed an effort to measure vapor intrusion in a neighborhood in Somerville, Mass., which is just north of Boston. The researchers also developed models to investigate concerns about vapor contaminant entry into structures built atop contaminated sites. The Brown SRP collaborated with the Boston University SRP, as well as Viridian Energy, to investigate vapor intrusion.

Vapor intrusion occurs when vapors in subsurface soils leach into indoor spaces, contaminating indoor air. The researchers investigated a neighborhood with known vapor intrusion issues related to releases of chlorinated solvents from an adjacent industrial site.

The impetus to Brown's vapor intrusion research efforts came from the Rhode Island Department of Environmental Managements (RIDEM). Over seven years ago, RIDEM noted their difficulty in assessing vapor intrusion as a source of exposure, and asked Brown to explore improving modeling and assessment approaches. This led to a significant investment by Brown's Research Translation Core and vapor intrusion research project to develop improved modeling approaches for this problem. The collaborative project received a supplement from the American Recovery and Reinvestment Act (ARRA).

Researchers in this project provided data that can help improve vapor intrusion characterization and risk assessments. The research is still ongoing and is expanding Brown SRP's current vapor intrusion work. This field study data is being analyzed and incorporated into models so that exposure and risk can be more thoroughly evaluated.

Measuring Benzene Exposure by Evaluating Biological Response

Stephen Rappaport, Ph.D., who was then at the University of North Carolina-Chapel Hill SRP, and Martyn Smith, Ph.D., from the University of California-Berkeley SRP, collaborated in research that led to a more detailed understanding of benzene carcinogenicity. Together, they developed and applied biomarkers of benzene exposure and investigated changes to gene expression and DNA that marked benzene effect.

They have measured biomarkers in over 1000 benzene-exposed workers and controls in numerous studies. Among their findings, they showed that beneze levels below 1 ppm cause a lowering of circulating blood cells and that benzene is toxic to progenitor cells – the unspecialized cells from which all other blood cells develop. They also found that benzene biomarkers increase with air concentrations, but in a non-linear fashion.

Developing a comprehensive set of benzene biomarkers let these SRP researchers to systematically explore benzene exposure-biomarker relationships over a wide range of occupational and environmental exposures. The biomarkers also let them to study the magnitudes of variability in human metabolism and evaluate associations between biomarkers and genotypic expression of several enzymes involved in benzene metabolism.

Airborne Exposure to Semi-Volatile Organic Pollutants in Urban and Rural Areas

The Airborne Exposure to Semi-Volatile Organic Pollutants (AESOP) project led by Peter Thorne, Ph.D., at the University of Iowa SRP, assessed exposures to atmospheric PCBs among an urban cohort in East Chicago, Indiana, and a rural cohort in Columbus Junction, Iowa. The East Chicago site is a high-exposure area contaminated with legacy pollutants from past industrial activity, and the Columbus Junction site is a low exposure rural area without any known local sources of PCBs.

In spring 2012, dredging of the Indiana Harbor and Ship Canal began placing 3.5 million cubic meters of contaminated sediment into a disposal facility adjacent to two East Chicago schools. The dredging project could potentially increase PCB exposures in the East Chicago community.

The researchers assessed the PCB exposures for the ethnically diverse cohorts through repeated blood sample collection and air sampling both inside and outside of homes and at local schools. PCB levels in household air samples and in blood demonstrate detectable levels for most lower chlorinate PCB congeners, and more than 37 congener groups were quantified in a majority of subjects.

The researchers continue to collect questionnaire data on personal and residential histories, consumption of local fish and game, and occupational exposures. They developed a mechanistically based bioaccumulation model that considers ingestion and inhalation exposures and will use it to evaluate PCB exposures in the cohorts.

AESOP investigators coordinate with the Iowa SRP Community Outreach and Education Core to work with school principals, science teachers, and community advisory boards from four East Chicago schools. This collaboration has been critical to the continued success of this community-based participatory research study.

Developing Analytical Tools and Methods

Hammock's Immunoassay Technologies Greatly Improved Detection of Hazardous Chemicals

Analysis of hazardous materials in the environment and levels of contaminants in people was greatly improved with the introduction of immunoassays that can measure contaminants in a variety of media such as water, air, and blood. Bruce Hammock, Ph.D., of the University of California-Davis SRP opened a new vista of possibilities when he first developed an immunoassay to test for the presence of pyrethroids, a class of pesticides.

Before this advance, testing various for contaminants involved complex equipment housed at universities and highly trained technicians. Samples had to get from the field to the lab, often under challenging conditions—remote locations, temperature extremes, difficult transport logistics. Immunoassays allow simple and sensitive measurements and can be used on multiple samples for quick results, often achieved on-site and at low cost.

Hammock saw great possibilities in the antibodies that were being used to detect proteins and other large molecules and developed a way to use immunoassays to detect chemical compounds. Immunoassay use has exploded since Hammock developed the first immunoassay for pyrethroids. They are now used to test for a vast number of chemicals using a wide variety of platforms, such as ELISAs and nanoparticle conjugates, and new developments continue to advance antibody-based methods.

Hammock has over 850 publications during his career, with a substantial proportion of them describing the development or use of immunoassays in environmental health. NIEHS has funded his lab continuously for 30 years, with SRP providing support for 25 years. The laboratory has over 30 patents, and its alumni include more than 65 graduates -- who now hold positions of distinction in academia, industry, and government -- as well as over 300 postdoctoral fellows, visiting scientists, international scholars, and collaborators. Two companies were spawned to translate research advances. Furthermore, the value of Hammock's lifetime work in environmental science was recognized by his nomination to the National Academy of Sciences in 1999.

His team continues to develop immunoassays, such as assays for the insecticides permethrin, fipronil, and chlorantraniliprole as well as polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol A, and the newly emerging environmental contaminants triclosan and triclocarban. Without a doubt, Hammock's ongoing efforts to push forward the technology to detect contaminants are greatly advancing our ability to prevent and reduce environmental exposures

Determining Susceptibility to Environmentally-Induced Toxicity

Clement Furlong, Ph.D.
(Photo courtesy of Clement Furlong)

Clement Furlong, Ph.D., and his research group, have greatly contributed to our understanding of the role of the paraoxonase 1 gene (PON1) in the metabolism of organophosphate pesticides. With funding from SRP, his group developed the concept of "PON1 status." This assay characterizes genotype and phenotype to determine how rapidly an individual will metabolize a toxicant. Furlong and his research group also developed an animal model to investigate the importance of PON1 variability in determining sensitivity to organophosphate exposures. This study identified the potential role of PON1 in protecting against the acute toxicity of specific organophosphate exposures.

Furlong continues his work by identifying biomarkers of exposure and susceptibility to organophosphates and related compounds. His research contributes to our understanding of how genetic and developmental variability affects how sensitive someone is to the toxicity of organophosphate pesticides and helps reduce the uncertainty in risk assessment.

Furlong's work was considered in the EPA's decisions to restrict use of chlorpyrifos and diazanon, and the State of Washington incorporated his findings on genetic and developmental variability in resistance to organophosphate pesticides into its pesticide training program. In addition, "PON1 status" is used by laboratories around the world to investigate risk factors for disease or exposures.

Real-Time Vapor Intrusion Monitor

With SRP SBIR support, Lynntech Inc. demonstrated the proof of concept for a compact and easy-to-operate vapor intrusion monitor that provides rapid test results. The real-time, portable, direct-reading air monitor detects vapor intrusion at trace levels and operates without human intervention for an extended period of time.

Vapor intrusion is the migration of volatile chemicals from subsurface soils into indoor air spaces of overlying buildings. These volatile chemicals can come from buried waste or contaminated groundwater.

The air monitor uses solid phase extraction for selective capture and pre-concentration of volatile organic compounds, and infrared fingerprinting to unambiguously identify analytes. The device can be used inside or outside of a building to monitor volatile and semi-volatile toxic chemicals such as TCE, PCE, PAHs, and PBDEs.

"Without this funding, we would not have been able to establish the feasibility of this technology and advance our innovative approach to the next development stage," said Bikas Vaidya, Ph.D., senior research scientist at Lynntech and leader of the SBIR project. Development of a field-deployable prototype and field-testing to gather data and identify improvement opportunities are planned for the second phase of the project.

Gellyfish Measures Bioavailability of Multiple Contaminants in Aquatic Ecosystems

Gellyfish mounted in snap-together slide holders are placed in a plastic basket for field deployment.
(Photo courtesy of Harvard University SRP)

The "Gellyfish" is a passive sampling device that can simultaneously measure the free metal ion concentration of multiple metals to determine the bioavailability of contaminants in aquatic ecosystems. James Shine, Ph.D., and researchers in his Harvard University SRP laboratory, developed and validated the sampler, which consists of a small amount of metal-binding resin within polyacrylamide gel. The device is a significant improvement over previous labor-intensive methods that could only determine speciation for one metal at a time.

The Gellyfish accurately quantifies free metal ion levels in metal mixtures within environmentally relevant concentration ranges. The analytical tool measures specific bioavailable forms of a contaminant, providing information helpful for understanding their bioavailability and subsequent risks to both human and ecological receptors.

Compared to other analytical methods for free metal ions, the Gellyfish sampler is inexpensive, rapid, reusable, and easy to use. Field application is also simpler than research conducted with animals because Gellyfish don't die, get eaten, or undergo gametogenesis during the test period. Unlike test animals, Gellyfish are all the same, reducing confounding influences such as age, size, and diet that are inherent in research with animals.

A significant advance in the area of metal bioavailability research, the Gellyfish greatly enhances our ability to estimate the potential fate and effects of heavy metals on the environment.

BRIDGES Assess Toxicity of Bioavailable Contaminant Mixtures

Graduate students led by Anderson sample in the Portland Harbor. (Photo courtesy of OSU SRP)

Biological response indicator devices for gauging environmental stressors (BRIDGES) are complementary passive sampling devices that bridge environmental exposure and biological response/effect. Passive sampling devices collect samples with a small badge-like device that relies on the diffusion of compounds toward a collection surface or sorbent. The diffusion barrier across the badge confers a constant, predetermined effective flow rate that is only slightly affected by temperature and unaffected by pressure (or altitude). After the sampling period, the device is capped and returned to a laboratory for analysis.

Developing bio-analytical tools to quantify bioavailability processes is important because bioavailability processes are embedded in human and ecosystem health risk frameworks. Concentrations measured by passive sampling devices can be used in cumulative risk assessments for air and water exposure and can be substituted for fish/shellfish tissue concentrations in existing health risk models. Adding passive sampler data to cumulative exposure and health risk models increases spatial and temporal precision, improves risk estimates, reduces animal collection, and lowers costs.

A research team led by Kim Anderson, Ph.D., at Oregon State University is using the devices to collect PAH samples in research conducted at the Portland Harbor Superfund site and in the Gulf of Mexico before, during, and after the impact of the Deepwater Horizon Oil Spill of 2010. This timely work is innovative because it addresses the gap between environmental exposures from an oil spill and biological responses using a time-integrated, bio-analytical system to selectively measure the environmental exposure that elicits a toxic response.

Luciferase Assay Reveals Toxins

Michael Denison, Ph.D., of the University of California-Davis SRP Program applied his extensive knowledge of aryl hydrocarbon receptor signaling to the difficult problem of tracking halogenated aromatic hydrocarbons (HAHs) contamination to develop the Chemically-Activated Luciferase Expression (CALUX®) system. The EPA now uses this system to evaluate contamination.

HAHs, such as polychlorinated biphenyls (PCBs), are global environmental contaminants present in food, water, and soil samples as well as in wildlife and humans. HAHs resist degradation, and exposure to potent HAHs, such as dioxin, can produce species and tissue-specific toxic and biological effects. These effects include reproductive dysfunction, birth defects, endocrine disruption, impaired immune function, and cancer.

Denison manipulated the intricate biological system for detecting and responding to HAHs to create a highly-specific, sensitive, and low-cost method for tracking dioxins and other HAHs using cultured cells. His technique uses aryl hydrocarbon receptor signaling to link HAH contamination to the production of a glowing luciferase reporter. The relative brightness of the luciferase glow reflects the level of HAH present in the sample.

The CALUX® system is a rapid assay that detects and quantifies dioxin-like chemicals and can be used for large screens. It has been accepted by the international community of governments and, in 2008, was included in the EPA's Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, known as SW-846.

In August 2012, the BG1Luc assay, a similar system developed by Denison, was accepted as part of the U.S. Environmental Protection Agency (EPA) Tier 1 screening program for estrogenic chemicals. The BG1Luc assay is based on hormone-stimulated transcriptional regulation and uses cultured cells that express estrogen receptors which, when stimulated by estrogenic compounds acting as agonists or antagonists, modulate the expression of an estrogen promoter regulated luciferase reporter gene.

The BG1Luc provide a useful platform for testing the endocrine-disrupting activity of various compounds or contaminated substances and shows the applicability of Denison's concept to multiple cell-surface receptor driven pathways.

Low-Cost Chemical Sensors Detect and Monitor Water Contamination

The low-cost sensor developed by Seacoast Science is capable of detecting chlorinated solvents at levels low enough to meet EPA drinking water standards.

Seacoast Science Inc. is developing an innovative low cost sensor system for detecting and monitoring dense non-aqueous phase liquids in the subsurface and groundwater. Seacoast demonstrated the feasibility of using the microsensor array with a proprietary trap-and-purge preconcentrator to detect chlorinated solvents, specifically TCE and TCA, at levels low enough to meet EPA mandated levels for drinking water.

The technology can be used unattended and in real-time from within a push-probe, using a chemicapacitor array and miniature preconcentrator. The system's sensor arrays monitor for leaks of toxic chemicals, contaminants from wastes, and changes in groundwater streams. Seacoast is currently developing new materials to improve the sensor array selectivity.

The most important application to public health and safety is unattended monitoring of drinking water, water treatment processes, and water sources. Potential markets include building chemical process monitoring and control, toxic vapor leak detection, industrial process control, and industrial health and safety.

Real-Time Analysis of Multiple Components in Exhaust

A team of SRP researchers, led by Catherine Koshland, Ph.D., at the University of California-Berkeley, collaborated with scientists at the Lawrence Berkeley National Laboratory to accomplish real-time, continuous monitoring of a variety of compounds commonly found in combustion effluents. The technique uses excimer laser fragmentation fluorescence spectroscopy to detect and quantify multiple components in combustion exhausts.

The technique uses high-energy photon beams to fragment the contaminants, which can then be optically detected by laser-induced fluorescence. The method can simultaneously detect different airborne compounds, and the researchers have shown it works for chlorinated hydrocarbons, barium, chromium, manganese, nickel, lead, and tellurium. The spectroscopy technique detects in real time and also *in situ*, and it can measure and identify minute traces (in the ppb range) of toxins based on their unique fluorescence.

The standard practice for monitoring combustion by-products before the new approach involved lengthy procedures, including extractive sampling and lengthy sample preparation that can require several weeks to produce results. With the new method, monitoring data can be generated in real time as emissions are formed, allowing for rapid response and corrective actions if pollutants are being released. This breakthrough in emissions monitoring has had far-reaching effects for both public health and environmental protection by offering a novel approach to monitor combustion processes and allowing rapid response to toxic emissions.

Linking Hazardous Chemicals to Health Effects

HEALS Cohort Established to Understand Arsenic Toxicity

Habibul Ahsan, Ph.D., and a multidisciplinary team of researchers from the Columbia University SRP, established the Health Effects of Arsenic Longitudinal Study (HEALS) in Bangladesh to investigate health issues related to chronic exposure to arsenic in drinking water. HEALS is one of the first large-scale genomic studies conducted in a developing county, and it is providing important evidence for arsenic toxicity and potential effects at low exposure levels.

In Bangladesh alone, an estimated 35 to 77 million people depend on well water that is contaminated with arsenic. The researchers report that chronic exposure to relatively low levels of arsenic is associated with an increase in the mortality rate. This finding is highly relevant in the nearly 70 countries, including the United States, where communities are faced with chronic low-level arsenic exposure.

The study identified small genetic variants that increased risk for skin lesions in people exposed to arsenic. The variants are found near the enzyme for metabolizing the chemical into a less toxic form, providing strong evidence that efficient metabolism of arsenic through methylation is protective. As a result, improving metabolism with nutrients or compounds that target methylation can improve metabolism of the metal. The study also showed that genetic differences may partially explain why some people exposed to arsenic get sick while others exposed to the same levels do not.

Along with studying the health effects of arsenic, HEALS also provides 20,000 people in the Bangladesh with basic primary medical care. Before the Columbia researchers arrived in the study region, there wasn't one doctor. Now the clinic has its own pharmacy and has the capacity to do X-rays, EKGs, and provide dental care along with primary health care.

"We refer to this program as a life altering experience," said Joe Graziano, Ph.D., the Columbia SRP Center Director. "Every time I go to Bangladesh, I am reminded of the magnitude of the problem. I am proud of the research and the translation into meaningful public health improvements."

Arsenic Exposure and Children's Intellectual Function

Joe Graziano, Ph.D., with a group of children in Bangladesh in the study region.
(Photo courtesy of Joe Graziano)

Arsenic in drinking water is significantly and adversely associated with child intelligence in a dose-response manner, according to a study led by Joseph Graziano, Ph.D. In the study, the Columbia University SRP investigated the intellectual function of 201 10-year-old children in Araihazar, Bangladesh, with highly variable exposure to arsenic in well water.

The study found that exposure to arsenic not only affects intelligence but also affects motor function in children. Importantly, the researchers found that children who experienced water arsenic concentrations greater than 10 micrograms per liter performed significantly more poorly than those exposed to less than 10 micrograms per liter. Although the EPA drinking water standard is currently 10 micrograms per liter, many regions around the world, and even in the United States, still have arsenic drinking water concentrations above the standard.

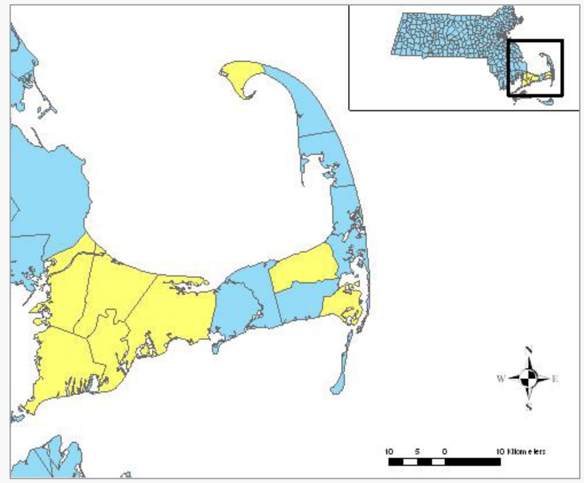
This landmark finding that arsenic exposure, like lead, is associated with deficits in child intelligence brings greater attention to low-level exposures to arsenic. Studies led by Graziano continue to investigate the health effects of low chronic arsenic concentrations in drinking water. This research has contributed to our understanding of the dose-response relationships between exposure to arsenic and health outcomes.

Studies Link PCE and Health Effects

Prenatal and early-life exposures to tetrachloroethylene (PCE) have been linked to a variety of adverse health effects in childhood and adulthood, according to studies led by Boston University SRP-funded researcher Ann Aschengrau, Sc.D.

Aschengrau's research team investigated the impacts of PCE exposure in a cohort born between 1969 and 1983 in the Cape Cod region of Massachusetts. In the eight towns involved in the study, a vinyl liner containing PCE was applied to pipes in the drinking water distribution system. The vinyl liner was improperly cured, leaching PCE into the water supply.

Aschengrau and her team associated prenatal PCE exposure to an increased risk for birth defects. Of the more than 2,000 women studied who lived in the area during the time of contamination, cleft lip and palate and neural tube defects were three times more common among babies exposed to PCE in the womb than among babies not exposed.



Eight towns on Cape Cod (highlighted in yellow) were used in the study. (Figure courtesy of Ann Aschengrau)

Other studies led by Aschengrau linked prenatal and early postnatal PCE exposure to visual dysfunction and adverse neurological effects, such as decreased attention and memory, in adulthood. The studies also uncovered a possible dose effect of PCE: higher early exposure may contribute to greater visual and neurological impairment.

Because of the prevalence of PCE, Aschengrau's studies show the need for further investigation of the health effects associated with PCE exposure.

Neurological and Metabolic Effects of Developmental Exposures to Toxicants

Postdoctoral fellow Cole Matson, Ph.D., now an assistant professor at Baylor University, performs killifish embryo injections. (Photo courtesy of Duke SRP)

Ted Slotkin, Ph.D., at Duke University SRP is studying the effects of developmental exposure to organophosphate pesticides on the brain as well as on metabolism, and has uncovered previously undefined mechanisms of toxicity. Organophosphate pesticides are generally classified as developmental neurotoxicants and have been shown to inhibit cholinesterase activities with a number of health effects.

Previous data from Slotkin's lab showed that developmental organophosphate exposure resulted in reduced numbers of neural cells and neurobehavioral deficits. To understand the mechanisms for these effects, the researchers evaluated gene expression in newborn rats after organophosphate exposure during the first four days of life. Chlorpyrifos and diazinon each resulted in changes in expression of 20 to 25 percent of genes related to cell cycle and apoptosis pathways. Importantly, these effects were shown to be independent of cholinesterase and occurred at exposure levels below the threshold for inhibition of this enzyme.

Slotkin's research team is also investigating the toxic effects of organophosphate exposures on metabolism. It is increasingly clear that environmental chemical exposures early in life are contributing to the explosive increase in the incidence of obesity and diabetes. Fetal or neonatal exposures to chlorpyrifos, diazinon, or parathion resulted in sex-selective changes in serum lipids, leading to increased body weight in adulthood. In addition, Slotkin's prior findings showed that early-life organophosphate exposures produce metabolic profiles resembling initial stages of diabetes. Together the data indicate that organophosphates target important homeostatic mechanisms that govern metabolism, growth, and risk factors contributing to diabetes, obesity, and cardiovascular disease.

Health Effects of the World Trade Center Disaster

The World Trade Center collapse created a huge urban disaster site with high levels of environmental pollutants.
(Photo courtesy of Philip Landrigan)

Following the Sept. 11, 2001 attacks on the World Trade Center, the Mount Sinai SRP received supplemental funding from NIEHS to study the health effects of toxic environmental exposures resulting from the destruction of the World Trade Center.

The three programs launched in the aftermath of Sept. 11, 2001 were clinical and epidemiological studies of workers who were at Ground Zero, a prospective follow-up study of 182 pregnant women who were inside or nearby the World Trade Center at the time of the attacks, and a pediatric outreach program intended to provide evidence-based guidance to government officials and practitioners on assessing and managing World Trade Center-related hazards to children.

Studies revealed that workers who were at Ground Zero showed new onset cough, wheeze, and phlegm production and intense respiratory symptoms because of the high alkalinity of the dust at the site. Another major finding was that the incidence of intrauterine growth restriction doubled in infant's mothers who were inside or near the World Trade Center on Sept. 11, as compared to controls.

"If SRP had not rapidly provided funding in the immediate aftermath of the attacks on the World Trade Center, the whole series of studies that followed would never have gotten off the ground and our knowledge of the consequences of those terrible events on human health and the environment would be very much the less," said Philip Landrigan, Ph.D., center director of the Mount Sinai SRP. Landrigan took the leadership role in preparing a major review article for publication in *Environmental Health Perspectives* that presented a comprehensive description of the studies to assess the health and environmental consequences of the World Trade Center disaster.

Residential Exposure to PCBs and Pesticides May Increase the Risk of Leukemia

To better understand the increased incidence of childhood leukemia in industrialized countries between 1975 and 2004, Patricia Buffler, Ph.D., and Catherine Metayer, Ph.D., from the University of California at Berkeley studied how Superfund chemicals affect a child's risk of leukemia. They evaluated benzene, PAHs, PCBs, and other Superfund chemicals in the homes of nearly 400 children and found that detection of PCBs in the home was associated with a two-fold increase in risk for acute lymphocytic leukemia.

Buffler and Metayer collaborated with Mary H. Ward, Ph.D., and Joanne Colt, from the National Cancer Institute Division of Cancer Epidemiology and Genetics, to measure the concentrations of persistent organochlorine chemicals in the children's homes. Using a specialized vacuum, they collected carpet dust samples from the room where a child spent the most time before being diagnosed with acute lymphocytic leukemia.

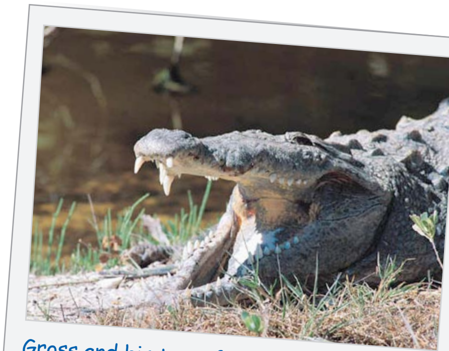
The study included 184 participants with acute lymphocytic leukemia, who were up to 7 years old, and from 35 different counties in northern and central California. As a control group, 212 children without leukemia were matched to cases by birth date, sex, and race, and Hispanic ethnicity.

The researchers found that the detection of any PCB-related chemicals in the dust conferred a two-fold increased risk of acute lymphocytic leukemia. Compared with those in the lowest quartile of total PCBs, the highest quartile was associated with about a three-fold risk, and the positive trend was significant. These findings helped show that PCBs, which are probable human carcinogens and cause perturbations of the immune system, represented a previously unrecognized risk factor for childhood leukemia.

Effects of Chlorinated Hydrocarbons on Wildlife

SRP-funded researchers at the University of Florida led by Tim Gross, Ph.D., linked pesticide exposure with the reduced fertility, reduced fecundity and abnormal sexual development they observed in alligators and fish from several central Florida lakes.

They determined that alligator and fish females with high levels of pesticides exhibited a variety of health effects related to reproduction and development of offspring. Alligators from impacted sites produced smaller eggs, and embryos often failed to develop normally. Although bass were able to spawn, they often produced juveniles that died during early developmental stages.



Gross and his team found that alligators exposed to high pesticide levels produced smaller eggs and embryos often failed to develop normally.

The research team discovered that land reclamation activities, specifically flooding of land previously used for farming, had introduced persistent pesticides from the soil into the aquatic ecosystem. They communicated these findings to risk assessors at the Florida Department of Environmental Protection, who made changes such as determining soil pesticide levels and remediating soil, if necessary, before flooding.

In the course of this work, the researchers developed tools to monitor the effects of endocrine-disrupting environmental chemicals. These new sensitive tools provide rapid methods to determine whether or not endocrine-disrupting chemicals are present. The tools can be used for initial screening of sites, prior to more extensive chemical analysis and can also be used to monitor clean-up of previously impacted sites.

Arsenic as an Endocrine Disruptor

The Dartmouth College SRP group led by Joshua Hamilton, Ph.D., was the first to report that arsenic is a potent endocrine disruptor that can broadly alter the behavior of a wide range of nuclear hormone receptors.

Hamilton and his team showed that arsenic at low doses appears to suppress the ability of all critical steroid receptors, including those for estrogen and testosterone, to respond to normal hormone signals. Studies led by Hamilton also revealed that arsenic can disrupt activity of the retinoic acid and thyroid hormone receptors. These two important members of the nuclear hormone receptor family are involved in normal development.

Given the myriad of functions modulated by hormone receptors, as well as the many diseases in which they have been shown to play a fundamental role, these receptors are likely one of the major pathways by which arsenic increases risk for the growing list of diseases associated with arsenic exposure.

Since hormone receptors were disrupted at levels far below 10 micrograms per liter in cell culture and at or below this level in several *in vivo* models, Hamilton's results suggest that drinking water levels of arsenic at or below the current EPA standard of 10 micrograms per liter may lead to adverse effects on human health.

PCB Exposure May Contribute to Obesity

Even low-level exposure to PCBs may contribute to the development of obesity and obesity-associated atherosclerosis, according to research from the University of Kentucky SRP project led by Lisa Cassis, Ph.D.

Obesity is at epidemic proportions in the United States, with 64.5 percent of the adult population considered overweight. Kentucky has the fourth highest prevalence of obesity in the nation. Because PCBs are highly lipophilic and accumulate markedly in fatty tissues, obesity could increase the burden of PCBs in the body.

The researchers looked at how PCBs affect the function of adipocytes, or fat cells, and the subsequent influence on cardiovascular disease. Cassis and her research team found that coplanar PCBs, which are ligands of the aryl hydrocarbon receptor, induce differentiation of adipocytes. This results in an increase in the accumulation of fat. In addition, these same types of coplanar PCBs promote inflammation in adipocytes, increasing risk for diabetes and cardiovascular disease.

Cassis' research reveals an association between PCB exposure and obesity and obesity-associated atherosclerosis. This discovery of the inter-relationships of PCBs, obesity, and obesity-related diseases contributes to our knowledge of nutrition and PCB toxicity in a way that can inform public health policy and practice.

Flame Retardant Exposure and Toxicities

Heather Stapleton, Ph.D., leads research teams at the Duke University SRP that focus on several types of persistent organic pollutants, including PCBs and brominated flame retardants. Much of her recent work has evaluated exposures and effects of PBDEs, with special interest in effects on the thyroid hormonal system.

A high-impact study out of Stapleton's lab showed that brominated flame-retardant chemicals are found in the polyurethane foam padding used in car seats, nursing pillows, portable cribs, sleep positioners, and dozens of other everyday baby products. Of 101 products tested, 80 samples contained an identifiable flame retardant additive, and all but one of these was either chlorinated or brominated. Stapleton and her team also identified two chlorinated organophosphate flame retardants not previously documented in the environment or in consumer products. This publication in the journal *Environmental Science & Technology* was named the top Science Paper of 2011 by the journal and was one of the top ten most-cited articles that year.

Stapleton is also co-investigator with Lee Ferguson, Ph.D., on a project that uses zebrafish as a model organism to study disruption of thyroid hormone metabolism. Although compounds such as PCBs and DDT are known or suspected to disrupt circulating levels of thyroid hormone, the mechanisms by which this occurs are not clear. Ongoing studies focus on metabolism of thyroid hormone within treated cells, as well a binding of T3 thyroid hormone to receptors. Because thyroid hormone plays a major role in growth and development, these findings could have important implications for understanding of the effects of these chemicals on children.

Phthalate Activation of Oxidative Stress in Gestational Tissues

Postdoctoral fellow Iman Hassan, Ph.D., works on measuring ROS in human placental cells exposed to phthalates.
(Photo courtesy of Northeastern SRP)

At Northeastern University, Rita Loch-Caruso, Ph.D., leads a team of SRP researchers investigating possible mechanisms by which environmental contaminants could promote the onset of early labor and increase risks for preterm birth. Her studies are focused on measuring oxidative stress in gestational tissues because this toxicological effect is known to be associated with early labor.

Loch-Caruso's group focuses on di-2-ethylhexyl phthalate (DEHP), which the body rapidly converts to the toxic metabolite mono-2-ethylhexyl phthalate (MEHP). The researchers found that in human placenta cells, MEHP significantly increased production of reactive oxygen species (ROS) and modified expression of several ROS-sensitive genes.

The researchers are now examining other gestational tissues. By demonstrating that a common toxicological effect, oxidative stress, activates biochemical pathways associated with early labor, this team's finding provides evidence for a plausible biological explanation for environmental pollutant exposure associations with preterm birth.

In Utero *PCB Exposures and Infant Development*

Harvard University SRP grantee Susan A Korrick, Ph.D., and her research team associated *in utero* PCB exposures with altered developmental achievement and growth in infancy and later childhood.

The study was performed with a cohort of 900 infant-mother pairs in a community adjacent to a PCB-contaminated harbor and Superfund site in New Bedford, Mass. It revealed that population exposure to PCBs may be associated with adverse effects on fetal maturation and, therefore, be a modifiable risk factor for premature births. According to the results, infant visual memory may also be impaired by *in utero* PCB exposure, which is predictive of cognitive performance in later childhood.

The study led by Korrick found associations of altered growth and development with *in utero* PCB exposures.

Korrick also assessed children 8 to 10 years old residing in the community and whose development had been followed since birth. This cohort revealed that early life exposures to PCBs were consistently associated with adverse behaviors, particularly behaviors associated with attention deficit hyperactivity disorder (ADHD). The research team also observed that children from sociodemographically-disadvantaged environments were more susceptible to developmental toxicities from early life PCB exposure.

These findings are notable because although the cohort lives adjacent to a PCB polluted harbor, PCB exposure levels in this population were at levels likely to be seen in much of the general population. Improved understanding of the health effects of *in utero* PCB exposure is key in establishing ways to prevent certain developmental disorders in infancy as well as their long term effects.

Health Effects of a New Class of Airborne Pollutant

Clarifying the pulmonary and cardiovascular health effects associated with inhalation exposure to environmentally persistent free radicals (EPFRs) is a target project at the Louisiana State University SRP. EPFRs are a novel class of pollutant generated by the adsorption of halogenated hydrocarbons onto the combustion-generated particles found in airborne particulate matter (PM). Because the Louisiana State University SRP team only recently identified EPFRs, there are no air quality standards for EPFR-containing PM and a better understanding of the health effects of EPFR exposure is needed.

There is strong epidemiological evidence that increases in airborne PM are associated with increased asthma risk and complications as well as cardiovascular events. According to the researchers, EPFR-containing PM directly induces the maturation of dendritic cells, which orchestrate many pulmonary immune responses involved in asthma. They also demonstrated in rodent studies that EFPR exposure diminishes baseline cardiac function and increases cardiac vulnerability to ischemia.

Identifying the roles of EFPR-induced oxidative stress and inflammation in mediating the pulmonary and cardiac effects, and distinguishing the EFPR-specific damage caused by particulate matter, will be critical for properly characterizing the health hazards posed by different air pollution mixtures and will also help inform air quality standards based on the presence and relative levels of EFPRs versus inert PM.

Toxicogenomic Study of Largemouth Bass

Nancy Denslow, Ph.D., and David Barber, Ph.D., at the University of Florida SRP designed microarrays for studying the impacts of organochlorine pesticide (OCP) contamination on fish. They were able to link exposure to organochlorine pesticides in fish with adverse endocrine system effects.

The studies linked organochlorine pesticides to endocrine disrupting effects in largemouth bass.

Denslow and Barber studied poorly-reproducing, non-flourishing populations of largemouth bass in Central Florida lakes that were contaminated with high levels of organochlorine pesticides, including p,p'-DDE (a DDT residual) and dieldrin. Initial studies suggested that organochlorine pesticides have complex effects on the endocrine system, likely affecting steroid receptors directly and altering endogenous hormone signaling.

Studies led by Denslow and Barber demonstrated that long term exposure of largemouth bass to organochlorine pesticides during their reproductive phase, produces complex compound- and gender-specific effects that involve all parts of the fish endocrine system, from the hypothalamus to the gonad and liver. This work also demonstrated the potential to rapidly create the tools necessary to assess large-scale transcriptional responses in non-model species, paving the way for expanded impact of toxicogenomics in ecotoxicology.

Transformation of Human Bladder Cells by Low-Level Arsenic Exposure

Exposure of bladder cells to arsenic in culture transforms the cells into tumor cells. (Photo courtesy of University of Arizona SRP)

Arsenic is a known human bladder carcinogen and the current EPA Drinking Water Standard (10 micrograms per liter) is based on the incidence of bladder cancer in arsenic-exposed populations. Although there has been a great deal of research on arsenic-induced bladder cancer and the toxic and carcinogenic effects of arsenic, the molecular mechanisms underlying arsenic-induced bladder carcinogenesis are still not well understood.

A. Jay Gandolfi, Ph.D., at the University of Arizona SRP, is studying the molecular mechanisms of carcinogenesis in a human bladder cell line. Previous research demonstrated that short-term exposure (3 months) of a human bladder cell line to a metabolite of arsenite (monomethylarsonous acid) at levels found in the urine of arsenic-exposed people caused the cells to transform into cancerous cells. The level of exposure was below the 10 micrograms per liter water standard.

Gandolfi's team found that short-term, low-level exposure to arsenic triggers a cascade of signaling in the bladder cells that causes them to grow faster and to increase in size. The arsenic exposure appears to alter how oxygen is handled by the bladder cells, making some of the oxygen reactive, which results in damage (single stranded breaks) to the DNA of the bladder cells. This damaged DNA is not repaired since arsenic also inhibits the normal repair mechanisms. As a result, right before the cells transform into tumor cells, there is a dramatic change in the global gene expression in the cells.

These studies show that arsenic concentrations below the EPA Drinking Water Standard can cause cells to become cancerous and that only a short exposure to arsenic produces irreversible changes in cells that ultimately progresses to a cancer. Gandolfi's method with bladder cell lines also provides a system for examining critical events that lead to arsenic-induced cancer.

Linking Arsenic to Cancer

The recognition of arsenic as a major environmental carcinogen is largely due to the work of epidemiologist Allan Smith, Ph.D., and his group at the University of California-Berkeley SRP. This research provided definitive evidence that arsenic in drinking water causes bladder, lung, and other internal cancers.

Their arsenic research activities began in the early 1990s with a risk assessment focusing mainly on cancer. This work, conducted under SRP Program Director Martyn Smith, Ph.D., led to the conclusion that the cancer risks from inorganic arsenic in drinking water were potentially very high. The Arsenic Health Effects Research Program was then started with funding from the SRP to study the health risks from exposure to inorganic arsenic. Currently, it involves international research projects, including studies and investigations in Argentina, Chile, India, and Bangladesh as well as California and Nevada in the United States. Employing novel biomarkers for arsenic exposure developed in Martyn Smith's laboratory, researchers observed effects on bladder epithelium at or around the U.S. drinking water standard at the time of 50 micrograms per liter (it has since been lowered to 10 micrograms per liter).

These SRP-sponsored epidemiological studies and arsenic biomarker development, made clear the severe health impacts of arsenic. This work made arsenic-related cancers a health research priority and led to additional funding to investigate arsenic dose-response relationships in greater detail.

Superfund Chemicals and Salmon Olfactory Injury

Gallagher investigates the effect of Superfund chemicals on Salmon olfactory injury.

Evan P. Gallagher, Ph.D., at the University of Washington SRP is studying how chemicals interfere with olfactory behavior in salmon. He is also developing biomarkers of exposure and olfactory injury. His work will allow researchers to identify problematic field sites and at-risk salmon populations, and to evaluate the success of Superfund site remediation efforts.

This project is investigating mechanisms by which low levels of environmental chemicals representative of those encountered at Superfund sites can negatively interfere with salmon olfactory behaviors.

Microarray studies by Gallagher and his research team have found that exposure to copper, a common environmental contaminant that disrupts salmon olfaction, specifically impairs molecular pathways in the Coho salmon olfactory system that are important in maintaining normal olfactory signal transduction. Without proper olfactory signaling, salmon cannot translate chemical cues in the environment into appropriate behavioral responses, which can impact their survival. The disruption of gene expression in these olfactory pathways occurs at low metal concentrations that are relevant to environmental exposures and below those established by water quality guidelines.

Companion studies revealed perturbed gene profiles in the olfactory system of zebrafish exposed to mixtures of copper and chlorpyrifos, including impaired signaling common to both chemicals.

Modulating Risk of Exposures

Nutrition Can Modulate PCB Toxicity

Bernhard Hennig, Ph.D., at the University of Kentucky SRP leads a research program examining how diet affects the cytotoxicity of environmental contaminants. He examines the PCB contaminant levels in food as well as how diet can influence the toxicity of PCBs. The Hennig laboratory has discovered that some items in the diet can activate mechanisms that increase cellular dysfunction while others can protect against cell damage mediated by PCBs.

Hennig's laboratory demonstrated that the type of fat in the diet, not just the amount of fat, can make a difference in cell damage triggered by environmental chemicals. In animal studies, PCB exposure induced atherosclerosis, for example. But when Hennig fed mice a diet enriched with olive oil and then exposed them to PCBs, the chemical had little negative effect on their fatty acid profiles. Mice fed a diet enriched with corn oil showed significant changes in serum fatty acids and increased vascular inflammation after PCB exposure. Hennig and other researchers also found that a high ratio of omega-3 to omega-6 fatty acids can reduce cell damage caused by PCBs and other pollutants.

Data from Hennig's laboratory also indicate that food components such as vitamin E and dietary polyphenols (e.g., green tea catechins) and certain polyunsaturated dietary fats interfere with oxidative stress-sensitive and pro-inflammatory signaling pathways in a way that protects endothelial cells from damage mediated by PCBs.

Even with the best remediation efforts, it's nearly impossible to remove all the chemicals at a given site, according to Hennig. Nutrition may become the simplest form of risk reduction. To this end, the University of Kentucky SRP Research Center uses nutrition education as part of its community engagement efforts. Working with the Center's Community Engagement and Research Translation Cores, trainees affiliated with Hennig's group helped communicate the importance of nutrition to Superfund communities in Eastern Kentucky as well as to officials and regulators associated with Kentucky's Energy and Environment Cabinet.

Folic Acid Supplement Lowers Blood Levels of Arsenic

Mary Gamble, Ph.D., of the Columbia University SRP, demonstrated that folic acid supplementation facilitates arsenic methylation and elimination, thereby lowering blood arsenic concentrations. Her research provides information that can be used to develop interventions for preventing arsenic toxicity and may have significant impacts on public health and policy.

Gamble's research team studied Bangladeshi adults who were part of the Health Effects of Arsenic Longitudinal Study (HEALS) cohort. The team documented a high prevalence of folate deficiency and abnormally high blood levels of homocysteine in this cohort. These conditions are caused by deficiencies in folic acid, B6, or B12 and are associated with a reduced capacity to methylate arsenic.

Gamble's team measured total arsenic and arsenic metabolites in the blood of 130 participants with low plasma folate. After 12 weeks of supplementation with folic acid or placebo, participants who received the folic acid had lower total blood arsenic concentrations than those receiving the placebo. The lowered levels of arsenic resulted from increased methylation of arsenic into a more soluble metabolite that is rapidly excreted in urine.

Gamble concluded that therapeutic strategies that facilitate arsenic methylation, particularly in populations with a high prevalence of folate deficiency and/or high levels of homocysteine in the blood, may lower blood arsenic concentrations, and thereby contribute to the prevention of arsenic-induced illnesses.

Giving Calcium to Nursing Mothers Lowers Their Lead Levels

A Harvard University SRP study led by Howard Hu, M.D., Sc.D., found that supplementing breast feeding women with calcium lowers their blood lead levels and reduces lead exposure to their infant. The supplement was particularly helpful for women with high bone lead levels, who experienced a 16 percent decline in blood lead levels with calcium supplementation.

Pregnancy and breast-feeding are known to cause a marked turnover of lead stored in bones, which account for 95 percent of lead found in adults. Therefore, lactation places women and their breast-fed infants at an increased risk of lead exposure

The study was part of the Harvard-Mexico Project on Maternal-Fetal Lead Exposure, Risks, and Prevention, which involves a partnership with investigators at the National Institute of Public Health in Mexico. The researchers conducted a double-blind randomized clinical trial to determine if taking 1,200 mg of calcium each day lowered blood lead levels in lactating women in Mexico City. This city has a unique environmental lead exposure profile because leaded gasoline began to be phased out in 1992, leaving many women with low blood lead levels but high bone lead levels.

This kind of intervention is not intended to be a substitute for public health efforts to reduce environmental lead exposure from all sources. However, it may constitute an important secondary prevention effort, because dietary lead exposure is difficult to eradicate and lead exposure from long-lived bone stores is likely to persist for decades.

Reducing Exposure to Mercury from CFLs

Engineering students Love Sarin and Brian Lee display a nanoselenium-enriched cloth that can capture vapor from broken CFLs. (Photo courtesy of Brown University SRP)

The switch from incandescent light bulbs to energy-efficient compact fluorescent lamps (CFLs) represents a potential safety issue because CFLs contain 3 to 5 mg of mercury. A team of researchers at the Brown University SRP, led by Robert Hurt, Ph.D., discovered that a variant of a substance called nanoselenium can absorb most of the mercury emitted from broken and spent CFLs. The material could be used in container lining to help reduce exposure to mercury.

The team tested the vapor release and capture of 28 sorbents and variants, finding that a form of amorphous nanoselenium (without the conventional protein coat) was the most efficient and effective. Tests of the material on 1 to 5 mg of mercury in a sealed chamber show that it absorbed 99 percent of mercury vapor. The team then used the nanoselenium compound to create mercury-adsorbent container linings.

The lead student on this research project, Love Sarin, received his Ph.D. in 2009, and joined Banyan Environmental, a new venture dedicated to commercial development of mercury-capture technologies. Sarin and Hurt became the scientific co-founders of an SRP-spinoff company, which won an NSF-STTR small-business grant in 2009 to pursue the translational research and development needed to commercialize the product.

Remediation of Hazardous Chemicals

Phytoremediation of Organic Solvents with Hybrid Poplar Trees

SRP researchers studied phytoremediation potential of hybrid poplars at the SRP-funded test site. (Photo courtesy of the University of Washington SRP)

Milton Gordon, Ph.D., and Lee Newman, Ph.D., at the University of Washington SRP found that hybrid poplar trees can detoxify trichloroethylene (TCE), perchloroethylene, and carbon tetrachloride. These organic solvents are widespread industrial pollutants. The work represents the first development of transgenic trees to increase removal of a broad range of serious environmental pollutants.

Gordon and Newman applied plant physiology, agronomy, microbiology, hydrogeology, and engineering to design the remediation strategy for sites where the groundwater is contaminated with the organic solvents. Conventional remediation technologies for these compounds are expensive and time consuming, and result in the formation of toxic by-products.

In 1997, the SRP created a project supplement to establish a test site for the phytoremediation work with poplar trees. Based on their SRP-funded research, Gordon and Newman successfully demonstrated the effectiveness of their phytoremediation systems under a variety of conditions.

Accelerating Pump-and-Treat Arsenic Remediation

Steven Chillrud, Ph.D., and scientists at the Columbia University SRP, developed a way to increase the speed at which pump-and-treat remediation can remove arsenic. They applied the strategy to treatment at the Vineland Superfund Site, which was highly contaminated with arsenic.

Pump-and-treat remediation strategies involve pumping contaminated groundwater to the surface using a series of extraction wells, treating the groundwater to remove the contaminants, and then either re-injecting the water underground or disposing of it off site. The scientists used laboratory studies to determine that oxalic acid, a natural soil acid, could help increase the mobilization of arsenic and thus speed its removal using pump-and-treat methods.

The pump-and-treat remediation strategy was applied at Vineland Superfund Site. (Photo courtesy of the Columbia SRP)

The Columbia SRP team then carried out modeling and *in situ* field experiments. They found that injecting oxalic acid underground did increase the mobilization of arsenic from aquifer solids, which increased the amount of arsenic removed from the aquifer with each volume of water pumped out and treated. This new approach reduced the time necessary to remediate arsenic.

They used the strategy at the Vineland Superfund Site and greatly reduced the cleanup time, saving taxpayers an estimated $2.4 billion over the life of the project. Oxalic acid also shows promise for dramatically decreasing the time required to use pump-and-treat intervention to remediate other sites where contaminants are primarily associated with iron and aluminum oxide surfaces.

Microwave Technology for Granular Activated Carbon Regeneration

A Field Demo of microwave technology at McClellan Park. (Photo courtesy of Chang Yul Cha)

Chang Yul Cha, Ph.D., of the CHA Corporation is using microwaves to reactivate granular activated carbon used to remove VOCs at hazardous waste site. The process reduces the cost and waste streams associated with using granular activated carbon for remediation.

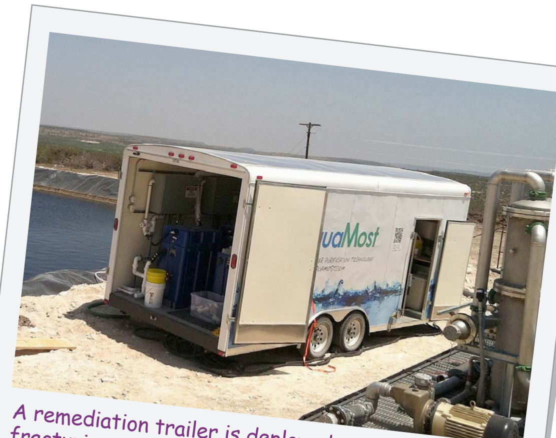
Granular activated carbon readily adsorbs VOCs, but as adsorption progresses the efficiency of the carbon decreases as available adsorption sites diminish. CHA's microwave-based regeneration process desorbs and captures a wide variety of chlorinated and non-chlorinated VOCs, allowing reuse of the activated carbon and recycling of the potentially valuable chemicals.

CHA Corporation designed, constructed, and tested a field-ready mobile microwave carbon reactivator. The system is compact enough to mount on a trailer, making it simple to regenerate carbon at any site. With SRP SBIR funding, the company conducted extensive design, laboratory, and scale up experiments as well as field tests at McClellan Air Force Base.

The technology concentrates, and therefore reduces, waste streams from hazardous waste sites, which can be more easily managed to prevent environmental contamination. The technology also has a cost advantage compared to remediation systems that rely on granular activated carbon disposal.

Device Treats Gasoline Contamination in Water

With SRP SBIR funding, Aquamost LLC developed a device that treats groundwater contaminated with organic pollutants released from leaking underground storage tanks. The company is also commercializing the technology to remediate water contaminated by hydraulic fracturing, which is used in the oil and gas industry. By treating wastewater onsite without chemical additives, the Aquamost system lowers operational costs and allows recycling and reuse of water from hydraulic fracturing.



A remediation trailer is deployed at a hydraulic fracturing site in West Texas. (Photo courtesy of Terence P. Barry)

"The grant funded the deployment of our novel water remediation technology in the field. We demonstrated the effectiveness of our solution and gained the real world insights we needed to engineer our devices for commercial success," said Terence P. Barry, Ph.D., co-founder and chief scientific officer at Aquamost. "With the grant and investor funding, our company grew from three employees to our present 20."

The device uses a technology called photo-electrocatalytic oxidation to remove aromatic hydrocarbons and fuel oxygenates from water. Both chemical classes have acute and long-term toxic effects and may be carcinogenic. For these reasons, considerable federal, state, and private resources are being expended to remove these chemicals from contaminated groundwater sites throughout the country.

DNAPL Remediation Methods Receive Patents

Researchers led by Cass Miller, Ph.D., at the University of North Carolina have patented two methods they developed for remediating contamination of subsurface environments. Dense non-aqueous phase liquids (DNAPLs) are heavier than and poorly soluble in water, making their removal a very difficult problem. The foundational concept for both patented remediation processes is simple: rather than fight the mass transfer limitations that exist in subsurface systems, exploit their potential for mobilization.

For the first approach, the researchers alter the density of water by injecting brine solutions so that the DNAPLs become lighter than water and float to the surface. The second approach is similar and uses a less dense brine barrier to funnel mobilized DNAPLs to a partially screened well or wells. Both processes can use surfactants to improve DNAPL recovery in highly heterogeneous areas of the subsurface. High fractions of DNAPLs (exceeding 90% of the initial mass) are removed relatively quickly. Moreover, the remaining DNAPL has a high surface area to volume ratio, which makes it relatively easy to remove using existing methods.

The researchers continue to develop and implement new approaches to remove DNAPLs from the subsurface. If these novel approaches are successful and put into practice, more economical means of contaminant source-zone remediation will reduce the risks to ecological populations, profoundly affecting the restoration of DNAPL-contaminated Superfund sites.

Revegetation of Mine Tailing Sites in the Southwestern United States

Specific types of plants and soil conditions are being investigated for their ability to stabilize areas contaminated with mine tailings. (Photo courtesy of University of Arizona SRP)

Piles of mine tailings cover thousands of acres in the western United States. Tailings are finely crushed waste rocks that are often acidic, contain toxic metals, and remain barren of vegetation. Many sites with tailing have very dry climates, which means that wind can spread tailings and associated metal toxicants over long distances and affect people living nearby. Raina Maier, Ph.D., and her colleagues at the University of Arizona SRP are assessing a strategy for long-term management of mine waste sites.

Revegetation is a relatively easy, cost-effective, and visually appealing approach, so Maier's team identified suitable native plants and identified greenhouse conditions that should allow these plants to grow in tailings. They then tested whether the greenhouse results would translate to the Iron King Mine Humboldt Smelter Superfund site in Arizona. In collaboration with EPA Region 9 and the site owner, the researchers initiated a field trial in May 2010 to test different compost amendment rates. In April 2011, they also tested the effect of adding lime and bacteria that promote plant growth.

The native plants and compost amendment concentrations that were optimal in the greenhouse also proved optimal in the field. Working with their colleagues in the lab of Eric Betterton, Ph.D., the researchers obtained preliminary data suggesting that establishing vegetation on mine tailings significantly reduces dust emission from the site. This reduction is especially true for small particle sizes (<PM10), which are most relevant for human health. The joint data from these projects will be the first to quantify the effect of revegetation on particulate emissions from a mine tailings site.

Remediation of Acid Rock Drainage

SRP SBIR grantee Blue Planet Strategies developed a method to profitably recover copper from acid rock drainage. The company also expanded the technology to include recovery of a variety of key metal toxins from acid rock drainage and practical removal and recovery of several additional components common to essentially all acid rock drainage.

The project led by Patrick James, Ph.D., targets profitable dilute metal removal and reclamation. These can create an economic driver that promotes environmental cleanup and stops the discharge of metal toxins. The new method is particularly valuable for the many abandoned mines leaking toxic acid rock drainage where no previous economic incentive to remediate exists. The work has resulted in two patents.

"The flexibility and consistency of the SRP support has enabled Blue Planet Strategies to weather the inevitable fiscal and time constraint challenges faced by startups that often kill young businesses," said James. "The result has facilitated introduction of the technology to the market, development of the business, and attention during the pivotal quest for non-SBIR funding to support the commercialization of the technology and building of a viable self-sustaining and job-creating business."

Clay Used to Reduce Groundwater Contaminants

Clay is well known for its strong sorptive capabilities, but it is also relatively impermeable when wet. Studies led by Timothy Phillips, Ph.D., at the Texas A&M SRP have shown that heat-treated clays can be chemically amended to increase their sorptive properties. In addition, he attached these clay particles to granulated activated carbon or sand to form a material called Claypac that has the sorptive properties of clay and the water permeability of sand or carbon.

This column contains a clay-based composite. (Photo courtesy of Texas A&M SRP)

Researchers in Phillips' laboratory used molecular modeling techniques to study and design chemically diverse materials for the sorption and detoxification of hazardous compounds. By bonding various organoclays onto quartz as a solid support, Phillips developed a Claypac media that is effective in removing many toxic contaminants from groundwater at wood-preserving waste sites.

Following initial bench studies, Phillips conducted field tests at a former wood-preserving facility in the northwestern United States, which is on the National Priorities List. Filtration columns packed with Claypac composites reduced the contaminant load from the oil-water separator effluent stream by 97 percent.

The native clays and sand that form the basis for the Claypac composites are abundant and readily available. Claypac shows great promise as an inexpensive, yet highly effective method for removing diverse organic compounds from contaminated waters.

Bioremediation Provides Powerful Solution to MBDE Groundwater Contamination

When a toxic chemical in the groundwater threatened to limit already strained water resources in California, SRP researcher Kate Scow, Ph.D., of the University of California-Davis SRP, found a solution based on her detailed understanding of bacterial metabolism and biodegradation of toxic compounds.

Methyl tertiary butyl ether (MTBE) reduces air pollution when added to gasoline and was used for several years in California before further studies revealed it also contaminates groundwater and is a probable carcinogen, according to the EPA. Although California discontinued MTBE use in 2002, many underground gas tanks at abandoned gas stations leak the chemical into groundwater. High MTBE readings in the water supplies of several California cites threatened to shut down treatment plants and limit already strained water resources.

Scow and her team worked together with Tesoro Petroleum and Haley & Aldrich Engineers to develop a bioremediation platform based on Methylibium petroleiphilum PM1. The PM1 microbe is naturally present in the MTBE-contaminated water and can degrade MTBE. By colonizing native PM1 in carbon filters, Scow and her colleagues and collaborators created water treatment bioprocessors that decreased peak levels of MTBE 10-fold in just two months, and eventually brought the aquifers into compliance and back online. The project won the National Groundwater Association Outstanding Project in Ground Water Remediation Award in 2005.

Low-Cost Method Uses Grass to Remove Mercury from Soil

Rabbit-foot grass removed mercury from soil and accumulated the contaminant within its plant tissues. (Photo courtesy of Edenspace)

Using physical and chemical remediation methods to remove mercury that contaminates soil is difficult and expensive. Thus SRP SBIR grantee Edenspace Systems Corp. studied the ability of rabbit-foot grass *(Polypogon monospeliensis)* to provide a less-expensive way to remove mercury.

Focusing primarily on wet ecosystems, researchers at Edenspace tested the ability of rabbit-foot grass to take up mercury and sulfur from soil and convert the elements to mercury sulfide in its plant tissue. Mercury sulfide has high stability and low solubility. Their experiments correlated mercury accumulation with mercury sulfide formation and demonstrated hyperaccumulation of mercury, with concentrations up to 110 times that of the control plant.

Phytoremediation, a process where plants remove, detoxify, or stabilize toxic substances, is not widely used for mercury, but this study reveals that it is a viable, low cost alternative for remediation of mercury at contaminated sites. The phytoremediation method could improve our ability to remove mercury from the global cycle and reduce human exposure. Edenspace is currently assessing the potential ecological risks of mercury sulfide-containing biomass and plans to perform field demonstrations at two mercury-contaminated sites.

Carbon Isotope Ratios Reflect Bioremediation Efficacy

Chloroethenes are among the most prevalent and problematic groundwater pollutants, and one solution to chloroethene contamination is *in situ* bioremediation. Quantifying the effectiveness of the biological processes, however, is difficult due to physical processes that also degrade chloroethenes in soil and sediment. Lisa Alvarez-Cohen, Ph.D., at the University of California, Berkeley SRP introduced a new way to evaluate chloroethene bioremediation by using carbon isotope ratios.

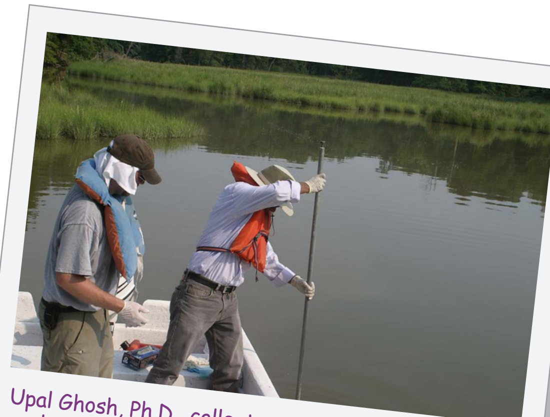
Alvarez-Cohen has demonstrated that quantifying shifts in stable carbon isotope ratios is a promising approach for evaluating the effectiveness of *in situ* bioremediation systems. Physical processes that breakdown chloroethenes cause minor or negligible shifts in isotope ratios, while biological conversion of organic compounds can cause significant changes in the ratio of carbon isotopes ^{13}C and ^{12}C, in both the reactants and products. In biological transformations, reaction rates tend to be faster for molecules with light isotopes than for molecules with heavy isotopes. As a result, the residual reactant becomes enriched with the heavy isotopes and the daughter products are enriched with the light isotopes. This enrichment (fractionation) can be measured using compound-specific stable isotope analysis.

Alvarez-Cohen's research group studied stable carbon isotope fractionation during the reduction of TCE using three test systems representing different types of microbes. The extent of fractionation varied widely, yet they observed constant enrichment factors within each culture. Additionally, isotope fractionation generated by a microbial community was quite different from that generated by isolated strains.

This research offered insights into the value of biological fractionation in assessing *in situ* bioremediation at contaminated sites and also demonstrated the complex nature of variable fractionation and the importance of accounting for site-specific factors to optimize estimates of degradation rates.

Activated Carbon Delivery for In Situ *Sediment Remediation*

Upal Ghosh, Ph.D., and researchers at the SRP R01 project at the University of Maryland – Baltimore County performed a pilot study that demonstrated that *in situ* treatment with low-impact delivery of activated carbon can useful for remediation of PCB-impacted vegetated areas and sensitive wetlands.



Upal Ghosh, Ph.D., collects samples from the site early in the project for characterization and to assess where to perform the field trial.
(Photo courtesy of Upal Ghosh)

Laboratory studies demonstrated that after amendment with activated carbon, there was a reduction in the bioavailability of PCBs and a range of chlorinated pesticides in sediment. Scientists performed a pilot field study at an EPA Superfund site contaminated wetland and a creek that flows into the James River in Virginia. They conducted bioaccumulation studies using the benthic organism *Leptocheirus plumulosus* and measured aqueous concentration measurement with a passive sampler, finding reductions in PCBs at the treatment sites two months after deployment. Benthic community sampling after application demonstrated no significant impact of the application on native biota.

This research provides a rationale for deploying activated carbon as a super-sponge for organic contaminants. This technology can be applied to sediment on a large scale to clean up an ecologically sensitive site without significant adverse effects on the ecosystem.

Novel Mechanism for Uranium Reduction via Microbial Nanowires

Gemma Reguera, Ph.D., with doctoral student Dena Cologgi, the first author on the PNAS paper published on the work with *Geobacter* bacteria.
(Photo courtesy of Gemma Reguera)

Gemma Reguera, Ph.D., led an SRP R01 project at Michigan State University that discovered the elusive uranium reductase pathway of *Geobacter* bacteria. This discovery provides critical mechanistic information that can be used to design schemes for *in vitro* bioremediation of uranium and other soluble, toxic metals.

Geobacter bacteria produce conductive protein filaments that function as nanowires. The group demonstrated that the nanowires bind soluble uranium and transfer electrons generated by the cell's metabolism. This reduces the uranium bound to the nanowires and also immobilizes it as a mineral on the protein filaments. They also demonstrated that by reducing the uranium outside the cell, the nanowires prevented the uranium from permeating the cell envelope, where it would have been reduced non-specifically by the electron transport chain and cause cell death.

This research could lead to the development of synthetic nanowires for deployable devices that remove radionuclides and toxic metals from sites where radiation or toxicity may prevent the use of the bacteria as bioremediation agents. These studies are innovative in that they integrate microbiological, physical, and nanotechnological tools to elucidate the novel mechanism of uranium reduction by microbial nanowires.

Anaerobic Microbes' Role in Bioremediation of PAHs

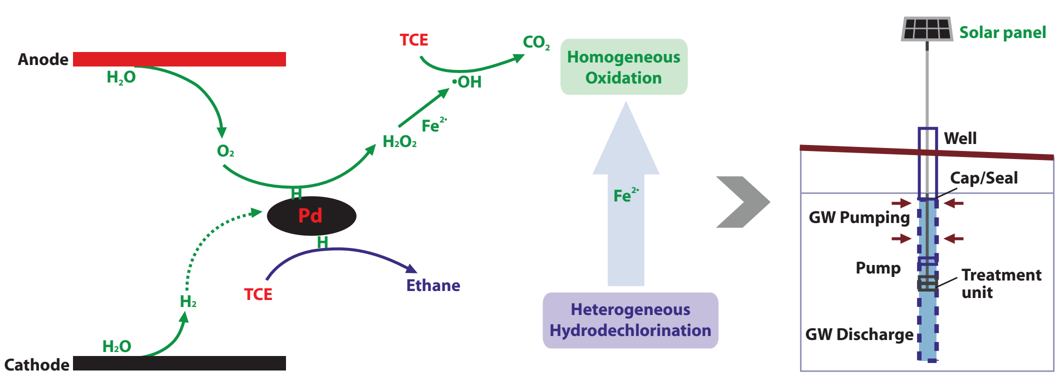
In an ongoing effort to describe mechanisms that control the fate of PAHs in the environment, researchers from the laboratory of Frederic Pfaender, Ph.D., of the UNC SRP program demonstrated the importance of anaerobic microbes in PAH biodegradation. They found that microbes are important for metabolizing and breaking down PAHs, as well as for conditioning the soil to promote biodegradation.

Anaerobic microbes may not metabolize PAHs, but they do increase soil pH, which enhances the solubility of PAHs and of organic matter in the soil. This anaerobic mobilization process releases sorbed PAHs and related non-polar byproducts from the soil, making the contaminants more available to the microbes that digest and degrade them.

Understanding the role of anaerobic mobilization in the release of soil-sequestered PAHs provided an important clue as to how to enhance bioavailability and bioremediation. This, in turn, led to simple methods to improve bioremediation, such as adding electron acceptors to soil to enhance anaerobic microbe activity.

Increasing the Efficiency of Trichloroethylene Remediation

Trichloroethylene (TCE), a known carcinogen, is a chlorinated hydrocarbon that is used as an industrial solvent and degreaser. TCE is also one of the most common soil and groundwater contaminants in the United States. A research team led by Akram Alshawabkeh, Ph.D., from the Northeastern University Superfund Research Program developed a new, low-cost strategy for remediating this contaminant.



Pd Catalyzes the degradation of TCE. The addition of Fe(II) ions shifts the reaction to a more rapid oxidative reaction.
(Diagram courtesy of Northeastern University SRP)

The new method uses iron ions (Fe(II)) and a palladium (Pd) catalyst to enhance oxidative degradation of TCE, which typically occurs as a side reaction during traditional TCE hydrodechlorination. Their method is particularly suited for sustained treatment of aquifers because a solar-powered system can be engineered for *in situ* implementation.

The researchers developed the method in the lab, where they applied mixed metal oxide electrodes to simulated TCE-contaminated groundwater to generate H2. Adding Pd powder catalyzed the reaction, which degraded TCE into ethane and other byproducts. The addition of Fe(II) increased the percent of TCE degraded from 40 to 95 percent within the reaction time frame of 80 minutes.

This work is the first to examine the ability of Pd to indirectly catalyze an oxidation process for groundwater remediation. This process could potentially be a low-cost and highly efficient method to remediate contaminated groundwater. The researchers have devised and are testing a new Pd-catalytic remediation system and an in-well solar-powered system.

Steam-Enhanced Extraction Maximizes Cleanup While Keeping Costs Down

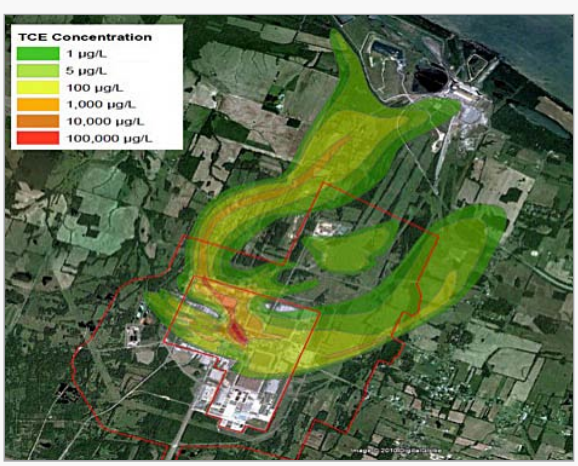
Kent Udell, Ph.D., and James Hunt, Ph.D., of the University of California-Berkeley SRP program developed a steam-enhanced extraction method that can remove trapped contaminants from soil more effectively and efficiently than previous technologies. Initial SRP funding led to a successful full-scale demonstration of steam-enhanced extraction at Lawrence Livermore National Laboratory and application at the Visalia Pole Yard in California – one of the first sites placed on the National Priority List.

Replacing traditional pump-and-treat methods at the Pole Yard with the steam-enhanced extraction method put the project approximately 190 years ahead of schedule and saved approximately $70 million. This project provides an excellent example of environmental research minimizing remediation costs while maximizing cleanup capabilities.

This SRP-funded remediation technology is also being used at Superfund sites, a Cape Canaveral launch complex, and other sites of national interest. At Loring Air Force Base in Maine, state officials and the EPA used the method to remediate fractured geologies. A pilot test is also underway at the Wyckoff Superfund site, which is adjacent to Eagle Harbor near Seattle. Internationally, steam-enhanced extraction is used routinely in the Czech Republic, including the first successful remediation of a fractured bedrock site, and has also been successfully demonstrated at the Pancevo site in the former Yugoslavia.

The effective application of steam-enhanced extraction has negated prior arguments that no technologies exist to remove heavy liquids from the subsurface and bolstered the push for aggressive environmental cleanup by regulatory agencies.

Water Purifier Harnesses Nanotechnology



TCE Plumes at the Paducah Gaseous Diffusion Plant.
(Photo courtesy of the UK SRP)

Dibakar Bhattacharyya, Ph.D., and other scientists at the University of Kentucky SRP developed a double membrane remediation system that removes chlorinated organic contaminants from groundwater. The device could offer an inexpensive way to provide clean drinking water in areas of the world where chemical contamination is prevalent.

The system uses nanostructured materials to generate hydroxyl radicals that can remove the contaminants. Although developed for environmental applications, the researchers believe that their approach could have other uses, including disinfection and virus inactivation. In addition to oxidative technologies, Bhattacharyya's group pioneered the synthesis of iron-based nanoparticles for toxic organic dechlorination using 'greener' approaches and responsive polymer membrane platform. In 2012, they filed three full U.S. utility patents based on the NIEHS-SRP work.

Lindell Ormsbee, Ph.D., and the University of Kentucky SRP Research Translation Core worked very closely with Bhattacharyya to find ways to implement his technology at the Paducah Gaseous Diffusion Plant. The plant is Kentucky's largest Superfund and has significant TCE and PCB contamination. These efforts led to additional funding from the US Department of Energy, and a treatability study proposal for the site is currently under consideration.

Poplar Tree System for Remediation of Organic Contaminants

Sharon Doty, Ph.D., works in the lab at the University of Washington with experimental poplar plants. (Photo courtesy of University of Washington)

SRP SBIR grantee Edenspace Systems Corp. determined that endophytes can break down TCE and improve the phytoremediation capability of non-transgenic plants. Endophytes are bacteria or fungi that live symbiotically within plant cells. Unlike other microbes that have been used for phytoremediation, endophytes live within the plant and are, therefore, expected to better persist at the site. They should keep degrading TCE as long as their plant partner survives.

Sharon Doty, Ph.D., at the University of Washington is a partner on the Edenspace project. She isolated a bacterial strain that exhibited high rates of TCE degradation from poplar trees growing at sites contaminated with TCE and other organic pollutants. This bacterial endophyte persisted in the roots of poplar trees and significantly enhanced the degradation of TCE compared to control trees.

Field-testing of this TCE-degrading bacterial endophyte is taking place at two sites with TCE-contaminated groundwater. A bacterial endophyte recently identified as a PAH degrader will also be tested in poplars with and without the TCE endophyte to determine the efficiency of this endophyte to degrade PAHs in the presence and absence of TCE.

Safe and Cost Effective Water Remediation with an Online Perchlorate Analyzer

With SRP SBIR funding, Advanced Microlabs LLC developed an on-line instrument to measure levels of perchlorate at water remediation sites.

Perchlorate is a small, highly water-soluble anion found as a contaminant in food and water supplies across the United States. Perchlorate interferes with iodide uptake of the thyroid, potentially decreasing production of thyroid hormones. This can lead to developmental delays in children and metabolic dysfunction in adults.

Advanced MicroLabs worked with a research group at Colorado State University to transform laboratory research into a commercial prototype for online analysis of perchlorate. They tested the prototype at a remediation pilot plant and demonstrated it had the resolution and reproducibility necessary to detect perchlorate and other ions. The company designed and built a prototype instrument and also fine-tuned the chemistry.

"We have taken this instrument in the field to a water remediation site and have shown potential customers our ability to measure perchlorate in the single digit ppb range," said Philippe Dekleva, senior research engineer and principal investigator of the project at Advanced Microlabs. "We are currently in discussions with both strategic commercial partners and investors to take our technology into production."

This instrument can perform on-line measurement of very low concentrations of perchlorate in water. (Photo courtesy of Philippe Dekleva)

Microbial Degradation of PCBs

Understanding the microbial degradation of halogenated polyaromatic compounds, mainly those with dioxin-like activity such as PCBs, polychlorinated dibenzofuran (PCDF) and polychlorinated dioxin (PCDD) is the focus of work conducted at Michigan State University SRP by James Tiedje, Ph.D., and his colleagues. Microorganisms play a major role in the environmental fate of these extremely stable compounds.

The researchers use a variety of molecular, culture-independent, methods to explore and recover genes for two key classes of enzymes involved in the transformation and detoxification of chlorinated polyaromatic compounds. They are studying dioxygenases, which act in aerobic environments, and reductive dehalogenases, which act in anaerobic environments. Knowledge gained about the anaerobic-aerobic process can be applied to the bioremediation of soils and sediments contaminated with PCBs.

The researchers characterized the diversity of dehalogenase and oxygenase gene sequences in microbial populations that metabolize AHR ligands in soils, sediments, and water. They found a larger diversity of aromatic dioxygenase genes than previously known.

Another critical question regarding bioremediation of highly insoluble organic pollutants, such as dioxins, is whether they are bioavailable to biodegrading bacteria. Tiedje and his colleagues have demonstrated that the chlorodioxin-degrading organism *Sphingomonas wittichii* strain RW1 completely degrades dioxin sorbed to the interlayer of clay particles.

The researchers have also applied stable isotope probing in aerobic experiments to find genes and operons involved in the degradation of (chloro)biphenyls. They used ^{13}C to probe for potential PCB-degrading populations in PCB-contaminated river sediment and recovered genes potentially involved in the first step of PCB degradation. The project should lead to better predictions of how contaminants behave in particular types of environments, thus decreasing uncertainty in risk and exposure assessments.

Understanding Metal Transporters in Plants

Julian Schroeder, Ph.D., at the University of San Diego SRP, has performed extensive research on transporters of toxic metals. His findings have improved our understanding of how plants detoxify metals and metalloids. This information could help scientists to modulate these transporters to engineer plants with increased metal absorption for phytoremediation. It may also be used to reduce metal accumulation in plants, such as rice, to minimize human exposures to metals that would typically accumulate in plants.

Schroeder and David Mendoza-Cózatl, Ph.D., collaborated with researchers at the University of Zurich and POSTECH in Korea to identify heavy metal-phytochelatin transporters in the plant *Arabidopsis thaliana*. They demonstrated that two genes (AtABCC1 and AtABCC2) code for vacuolar phytochelatin transporters, and are required for arsenic resistance. When both genes were deleted from the plant genome, the plants could not accumulate arsenic in their vacuoles.

Schroeder has identified numerous metal transporter genes and enzymes and was recognized for his work when he was named a Fellow of the American Association for the Advancement of Science. Among other findings, Schroeder's team, together with Paul Russell, Ph.D., identified a new transporter, Abc2, which is essential for cadmium tolerance and cadmium uptake into vacuoles in yeast.

New Methods to Examine Biofilm Treatment Systems

Scientists led by Paul Bishop, Ph.D., at the University of Cincinnati are working to better understand biofilms used to treat toxic wastewaters. Their research has provided a mechanistic understanding of biofilm treatment systems and knowledge that benefits engineers who design water treatment systems.

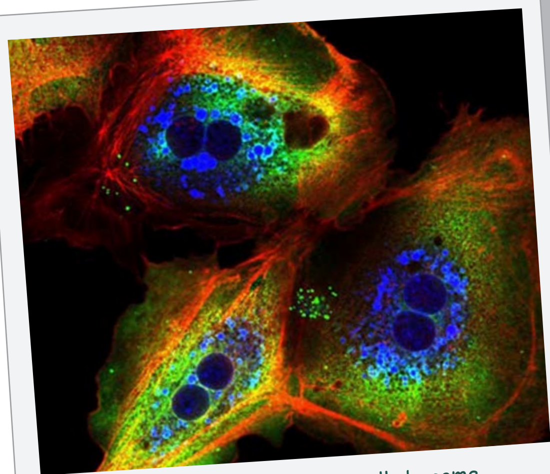
The researchers used biofilms to degrade a variety of azo dyes, which serve as model toxic organic compounds. Azo dyes range from easily biodegradable to essentially non-biodegradable and allow effective testing of biofilm degradation. They found that a type of Sphingomonas bacteria could aerobically convert these dyes into harmless end products without toxic intermediates. Using this microbe in wastewater biofilm reactors, the researchers achieved a nearly complete biodegradation of the azo dyes. They also developed a fluorescent antibody to analyze the number of bacterial cells and their locations in the biofilm.

The scientists then developed a series of microelectrodes to measure chemical conditions inside biofilms. The microelectrodes have a tiny tip and rapid response time, which enables direct and nondestructive measurements of conditions inside the biofilms. They can measure dissolved oxygen, pH, and redox potential profiles. To better understand physical biofilm structure, scientists used confocal scanning laser microscopy to observe the biofilm structure in fixed-film wastewater treatment systems.

The results have been applied to real-world wastewater treatment systems with the intent to extend investigations into soil bioremediation. Researchers investigating other toxic organic compounds undergoing biofilm treatment can make use of the analytical procedures developed by Bishop's research team and collaborators.

Understanding Mechanisms of Toxicity

Signaling and Oxidative Stress in Response to Chemical Carcinogens



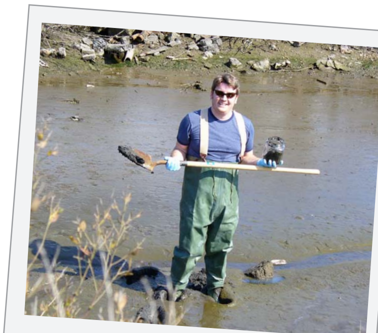
Karin's work identifies how liver cells become cancerous after exposure to chemical carcinogens.
(Photo courtesy of of UCSD)

Michael Karin, Ph.D., leads a team at the University of California-San Diego (UCSD) SRP that is investigating various signaling pathways that activate cellular processes in the body. Karin was elected as a member of the U.S. National Academies of Science in 2005 for his far-reaching and extensive work in identifying and characterizing signal transduction pathways that regulate gene expression in response to external stimuli. His work has increased our understanding of molecular links between inflammation, obesity, and cancer.

Karin's lab is studying the role of specific signaling pathways in the oxidative stress response to carcinogens. They are using a variety of genetic, cell biological, and biochemical approaches to search for new regulatory molecules, including protein kinases and transcription factors, that are involved in the oxidative stress response. Recent studies have identified key signaling pathways in tobacco smoke-induced lung tumorigenesis and in diethylnitrosamine-induced liver cancer. Using this information, Karin and colleagues are creating gene arrays, cell lines, and transgenic mice that can be used as biosensors for monitoring exposure to toxicants that cause oxidative stress.

Mechanisms of Resistance and Susceptibility to Polyaromatic Hydrocarbons

Superfund sites are often contaminated with complex mixtures of organic and inorganic substances. Richard Di Giulio, Ph.D., at the Duke University SRP is studying the effects of real-world contaminant mixtures on development in killifish *(Fundulus heteroclitus)*.



Postdoctoral fellow Bryan Clark, Ph.D., collects samples at Elizabeth River.
(Photo courtesy of Duke SRP)

This project grew out of Duke's long-standing relationship with a Superfund site at Atlantic Wood Industries Inc., on the Elizabeth River in Virginia. Polycyclic aromatic hydrocarbons (PAHs) and other compounds were discharged into the river from this wood treatment facility. A species of killifish at the site has developed resistance to the acute cardiovascular effects that typically result from exposure to PAHs in the river.

Although the fish show resistance to cardiovascular effects, they have increased risk of cancer, particularly liver cancer, later in life. In a series of experiments, Di Giulio showed that resistance to the cardiovascular effects was passed to offspring even when they were raised in the laboratory rather than in PAH-contaminated river waters. Resistant fish are also more sensitive to natural stressors such as low dissolved oxygen and ultraviolet light. Thus, this population provides a case study in "evolutionary ecotoxicology."

Graduate students Daniel Brown and Audrey Bone sample killifish at the Superfund site.
(Photo courtesy of Duke SRP)

Di Guilio's team continues to characterize toxicity mechanisms for PAHs and other chemicals. For example, recent data from his lab suggests important interactions between aryl hydrocarbon receptor (AHR) agonists, such as benzo(a)pyrene, with cytochrome P450 enzyme inhibitors such as flouranthene. Genetically modifying killifish embryos to lower their expression of AHR2 resulted in protection against acute cardiotoxicity for killifish exposed to PAHs.

A mechanistic understanding of contaminant-induced changes in gene expression and signaling pathways in these fish promises to improve our understanding of the long-term impact that sub-lethal pollutant exposure has on wildlife, which also has implications for human health.

Labeled Vinyl Chloride Reveals the Origins of Mutagenic DNA Adducts in Brain Tissue

By examining rodent DNA from brain and liver tissue following exposure to stable isotope labeled vinyl chloride, James Swenberg, Ph.D., and his research team at the University of North Carolina helped distinguish between the established role of vinyl chloride in liver cancer and its potential role in brain cancer. While this work provided further evidence that vinyl chloride damages liver DNA by producing harmful adducts that lead to mutations, it also showed that similar DNA adducts, though observed in the brain, were not caused by vinyl chloride exposure.

The mutagenic DNA adducts he observed in brain tissue were found in both vinyl chloride-exposed organisms and in unexposed controls, showing that this type of damage, which can result from vinyl chloride exposure, can also occur based on internal processes that involve oxidative stress, like lipid peroxidation.

The role of non-exposure related oxidative stress in generating harmful DNA adducts in the brain was made clear through the UNC studies, which showed adducts observed in brain tissue were not derived from vinyl chloride. Although vinyl chloride does distribute to the brain, it is not metabolized through a pathway that can lead to the type of damage it had been linked to in the liver. Likewise, damaging metabolites formed in the liver cannot be transported to the adult rat brain due to extreme instability. These findings showed it was unlikely that vinyl chloride-generated DNA adducts play a significant role in initiating carcinogenesis in the brain after exposure to vinyl chloride. Results with weanling rats were less definitive, suggesting age-dependent differences in susceptibility to vinyl chloride exposure.

Mechanisms of Dioxin Sensitivity and Acquired Resistance

Scientists led by Mark Hahn, Ph.D., of the Boston University SRP, discovered that killifish have differences in sensitivity to reproductive, immunotoxic, and carcinogenic effects of chlorinated dioxins and PCBs. They then identified and isolated the gene that codes for specific proteins that can inhibit the ability of dioxins and PCBs to cause effects.

Mark Hahn, Ph.D., with Research Associate Diana Franks.
(Photo courtesy of Boston SRP)

Their research, and that of investigators at the EPA laboratory in Narragansett, R.I., revealed that killifish in contaminated sites are much less sensitive to effects of PCBs and dioxins than killifish from less contaminated sites. This research also showed that resistance is passed on from parents to their offspring, suggesting that it is a genetic trait that has evolved in the killifish population.

Based on this finding, Hahn's group worked to identify the cause of dioxin and PCB resistance in NBH killifish in New Bedford Harbor, MA (NBH), a Superfund site highly contaminated with PCBs. In fish, as in mammals, the effects of dioxin-like chemicals occur through their interaction with the aryl hydrocarbon receptor (AHR). Hahn's group identified two distinct aryl hydrocarbon receptors (AHR1 and AHR2) in killifish and other species of fish, and investigated the role of these two receptors in the dioxin and PCB resistance that has evolved in NBH fish.

Understanding how dioxin and PCB resistance occurs in these highly exposed fish improves our ability to predict the sensitivity of humans and wildlife to these compounds. The research also helps us understand the long-term impact of chemicals at Superfund sites. For example, following the persistence or loss of resistance over time helps to evaluate the success of remediation at these sites.

Understanding Pollutant Fate and Transport

Transport and Exposure Pathways of Phthalates and TCE in Karst Groundwater Systems

Hydrogeologists Ingrid Padilla, Ph.D., and Dorothy Vesper, Ph.D., and graduate student Celys Irizarry examine well equipment installed through the Monte Encantado aquifer cave in Puerto Rico. They are examining contaminant transport in water over time in the highly complicated Puerto Rican aquifer system. Padilla is also a former SRP trainee. (Photo courtesy of Northeastern SRP)

Puerto Rico is facing concerns about groundwater contamination from mixtures of di-2-ethylhexyl phthalate (DEHP) and trichloroethylene (TCE). DEHP and TCE are suspected to contribute to Puerto Rico's high rate of preterm birth, the highest of any jurisdiction in the United States. Ingrid Padilla, Ph.D., at the Northeastern University SRP, is leading a project aimed at determining the principal fate and transport processes for mixtures of DEHP and TCE in in geologic formations known as limestone or karst aquifers, on the island.

Padilla's lab uses models to simulate flow behavior in karst aquifers, and these models can be used to assess fundamental transport processes. To better understand flow paths and water flow conditions, the researchers expanded the collection, compilation, mining, and geospatial mapping of historical contamination data along the north coast of Puerto Rico. They also established stronger collaboration for data sharing with the Puerto Rico Department of Health, Puerto Rico Environmental Quality Board, and the U.S. EPA.

Field sampling of groundwater wells and springs during dry and wet seasons, as well as tap water, is ongoing. Chlorinated volatile organic compounds (CVOCs) and phthalates were found in samples from wells and springs located outside demarked areas of Superfund sites, and analyses of historical and field data continue to show CVOCs and phthalates in the northern karst aquifers of Puerto Rico. This data supports the hypothesis that these aquifers have a large capacity to store and slowly release contaminants. Together these studies are providing crucial information about contaminants in the aquifers with the ultimate goal of reducing human exposures.

Sequestration of Dioxin by Clays

Clay minerals may be a major, but largely unrecognized, sink for Ah-receptor ligands (AhRLs) such as dioxin, according to Stephen Boyd, Ph.D., at the Michigan State University SRP. Naturally occurring clay deposits, commonly called "ball clays," are known to contain dioxin and have led to human contamination in potters and to livestock poisoning when used as feed additives. However, the degree to which adsorbed dioxin is bioavailable is unknown. Thus, Boyd is working to better understand the bioavailability processes involving dioxin-contaminated soils and sediments.

AhRLs have exceptionally low solubilities in water, and thus tend to occur in nature bound to some form of geosorbent such as soil or clay. Exposure to environmental polychlorodibenzo-p-dioxins (PCDDs) occurs almost entirely through ingestion or inhalation of adsorbed PCDDs. Although soil organic matter is generally considered the predominant sorptive compartment for organic contaminants, recent research by Boyd and colleagues showed that certain classes of organic contaminants have equal or greater affinities for clays.

Their studies revealed nearly identical relative bioavailability of TCDD delivered to mice in corn oil as when absorbed by smectite clay. Although TCDD may exhibit low bioavailability when adsorbed by carbonaceous geosorbents (e.g., chars), TCDD in clays is likely to be highly available for bio-uptake in mammals. This knowledge should be considered in risk assessment and in the development of remediation goals, especially for sites where clays represent a significant phase for TCDD sequestration.

Persistence of Organochlorine Pollutants in the Hudson River

As part of the Mount Sinai School of Medicine SRP, a team of researchers led by Richard Bopp, Ph.D., of the Rensselaer Polytechnic Institute, developed a comprehensive picture of the lower Hudson River's contamination with PCBs and other persistent organochlorine pollutants. This unique watershed-wide effort mapped the principal sources, plotted the environmental fate and transport, and noted the persistence of these compounds in the Hudson River and New York Harbor.

Bopp and his team also completed a detailed study of reductive dechlorination of PCBs at a highly-contaminated and a moderately-contaminated site on the Hudson. The highly-contaminated site was near an electrical manufacturing plant in Hudson Falls, N.Y. There, initial first-order rate constants were similar to those reported for *in vitro* studies. However, the overall PCB compositions at the site were not nearly as dechlorinated as typical laboratory-scale incubations after a few months. At the moderately-contaminated site, only the initial stages of dechlorination had occurred, even after several decades.

These findings have major implications for the environment and for public health. The principal implication is that PCB contamination of the Hudson River will persist decades longer than originally hypothesized in laboratory studies and that fish from the river will pose hazards to health and to fetal development for many years to come.

Predicting Mercury Burdens in Fish

Scientists from the Dartmouth College SRP, led by Carol Folt, Ph.D., and Celia Chen, Ph.D., collaborated with international scientists to investigate the bioaccumulation and trophic transfer of mercury. Through several studies, the researchers significantly progressed the understanding of mercury transport in the environment and its accumulation in fish.

Carol Folt, Ph.D., and Celia Chen, Ph.D.
(Photo courtesy of Dartmouth SRP)

The researchers sampled and analyzed mercury concentrations in a group of fish from Baiyangdian Lake in China. They noted that total mercury bioaccumulation did not consistently increase with trophic levels, but mercury concentration did increase with increasing fish size. Results also revealed lower dissolved and particulate concentrations of mercury in the presence of increasing algal blooms.

By evaluating data from four multi-lake studies in the United States and Canada, Chen and Folt found that lake types associated with the greatest mercury bioaccumulation were remote lake ecosystems where forests and wetlands enhanced the transport of mercury from watersheds to lakes. They also found that atmospheric transport and deposition are the major sources of mercury.

These findings shed light on how mercury moves through the food web in freshwater ecosystems and provide public health and environmental protection officials with information they can use to formulate site-specific fish consumption advisories.

Following the Fate of Toxic Metals in a Community Watershed

Harold Hemond, Ph.D., leads an SRP-funded research program at the Massachusetts Institute of Technology that is following the transport of arsenic and chromium through the Aberjona River in Woburn, Mass. The Aberjona River was polluted by tanning and other manufacturing activities and contains chromium, arsenic, and other hazardous chemicals that have also been found at several other sites throughout Woburn. This work helped determine the health risk associated with the area's metal contamination.

The researchers focused on identifying and quantifying metals delivered to former municipal wells that provided water to the Woburn community between 1964 and 1979. They developed a new piezocone technique to map and model the subsurface stratigraphy connecting the contaminated river to the aquifer that supplied water to municipal wells. The researchers discovered much of the arsenic in the Aberjona watershed originates as arsenite, a reduced species that is both more toxic and mobile than arsenate, another form of arsenic commonly found in the environment. The researchers also determined that much of the arsenite is discharged from a small man-made lake adjacent to the Industri-Plex Superfund site.

Because the Aberjona watershed includes parts of seven local communities in the Boston area and is used for fishing, swimming, and boating, understanding where pollutants are found, how they are transformed, and where they will be transported in the future has been critical to minimizing human exposures to toxic compounds.

Behavior of Nonaqueous Phase Liquids in the Subsurface

Nonaqueous phase liquids (NAPLs) are difficult to detect and treat, and tend to persist as a distinct organic phase that can serve as a continual source of air and water contamination. These troublesome compounds are so-named because when in contact with water, they form a separate layer or "phase" instead of dissolving. Linda Abriola, Ph.D., and her colleagues at the Michigan State University SRP are working to better understand the factors that influence the behavior of NAPLs in the subsurface environment.

The researchers used laboratory soil column experiments to evaluate the evaporation and persistence of tetrachloroethylene (PCE), a single-component NAPL, in a variety of sandy soils that represents the soil zone above the groundwater table. They quantified the mass transfer rates of PCE and found that the volatilization rates of entrapped PCE can be predicted from easily determined flow and soil parameters. For example, they found that when 99 percent of the contaminant is recovered, low levels continue to persist in the soil column for extended periods. This persistence is believed to result from slow release of the contaminant from the soil and/or water phases.

The researchers also conducted experiments that evaluated the influence of soil properties, namely chemical heterogeneity and grain size distribution, on the removal and degradation of PCE. Results suggest that even low percentages of organic-wet solids (i.e., solids saturated with organic matter) greatly enhance the breakdown of NAPLs.

This research will help scientists predict the environmental impact of NAPL contamination and provide information that can improve the effectiveness of cleaning up NAPLs in soil and aquifer systems.

Research Translation and Community Engagement

Dean Carter Binational Center for Environmental Health Sciences

Graduate students attend a specialized workshop in Taxco, Mexico. (Photo courtesy of the University of Arizona SRP)

The 2,000-mile border between the United States and Mexico is a unique arid region spanning four U.S. and six Mexico states. Environmental concerns along the border arise from a complex combination of regional, national, and international forces, including patterns of economic growth and trade, public policies, and demographic and social dynamics. Residents are at risk of exposure to a variety of environmental contaminants including arsenic, trichloroethylene, lead, pesticides, and particulate air pollutants.

Since 1990, SRP-funded researchers at the University of Arizona have worked to build an Outreach Core to address U.S.-Mexico Border health issues. This effort was initiated and led by Dean Carter, Ph.D., resulting in the establishment of the Dean Carter Binational Center for Environmental Studies and Toxicology, recently renamed in his honor. Carter emphasized that any effort to make significant improvements would require collaboration between the United States and our Mexican neighbors. In his words, “We share a border, share environmental problems, and we must share the solutions as full partners.”

University of Arizona SRP scientists partner with Mexican scientists to build collaborations, exchange and transfer environmental expertise, and develop coordinated strategies to assess exposure and characterize health effects. They are also developing preventive measures that both countries can use, and are applying remediation technologies to remove hazardous wastes.

Videos Simplify Issues Surrounding Arsenic and Mercury Exposure

Aiming to inform the general public about arsenic and mercury exposures, Dartmouth College SRP developed two ten-minute videos that explain research findings on arsenic in well water and mercury in seafood.

Celia Chen, Ph.D., introduces the mercury film at Red River theatres in Concord, N.H. Chen is featured in the film for her work on the fate of mercury in aquatic food webs. (Photo courtesy of Jared A. Rardin)

The arsenic film, “In Small Doses: Arsenic,” identifies high concentration areas of arsenic in New England and offers pointers for residents relying on wells for their drinking water, including the need to test well water on a regular basis. According to scientists in the film, up to one-quarter of the 2.3 million people who routinely consume water from wells in New England may be exposed to potentially harmful levels of arsenic. Although public water sources undergo regular testing, it is not a requirement for most private water systems.

The mercury film, “Mercury: From Source to Seafood,” explains how mercury gets into the seafood we eat and raises awareness of the health effects of mercury in seafood. It also describes the health benefits of eating low-mercury fish and the need to keep mercury from entering the environment.

The films are the first two in a series of videos created by the Dartmouth SRP to translate their relevant toxic metal research to the public.

Providing Safe Drinking Water to Families in Bangladesh

A Columbia University SRP team led by Alexander van Geen, Ph.D., helped families in Bangladesh to gain access to drinking water with lower levels of arsenic. By exploring the risk of arsenic and informing Bangladesh communities about safer wells, the Columbia SRP team greatly reduced arsenic exposure from drinking water.

The research team first studied wells in Bangladesh. The tests showed that groundwater arsenic concentration varies widely within a region, but the majority of shallow tubewells in Bangladesh have arsenic concentrations higher than 50 micrograms per liter, much higher than the U.S. standard of 10 micrograms per liter. The team also discovered that deeper wells generally had lower arsenic concentrations.

A child pumping low arsenic water at a newly installed deep, low-arsenic well in Bangladesh. (Photo courtesy of Joe Graziano)

With the help of other researchers at the Columbia SRP, the team raised money from donors to put in close to 100 deep community wells serving the Health Effects of Arsenic Longitudinal Study (HEALS) cohort study population in Bangladesh. The researchers then measured arsenic in urine of the adults in the study region, and over time urinary arsenic decreased, revealing the success of the deep-well campaign.

Since the installation of the first 100 wells, the deep-well switch was translated into national policy in Bangladesh. The government embraced the deep-well remediation strategy, and now there are more than 20,000 deep wells throughout Bangladesh, serving millions of people.

Boston Consensus Conference on Biomonitoring

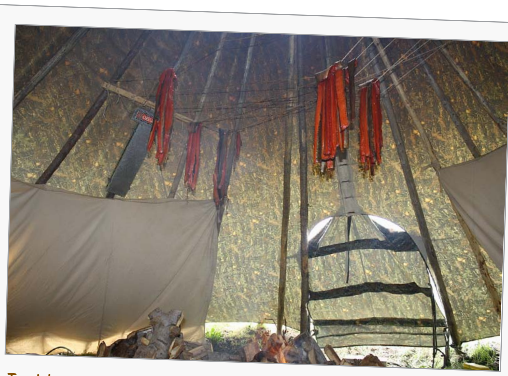
In 2006, Boston University SRP was involved in an extensive community outreach and research translation effort aimed at directly involving the public in science and technology policy and decision-making. Led by Madeleine Scammell, D.Sc., who also leads the Boston SRP Community Outreach Core and Research Translation Core, researchers put together the "Boston Consensus Conference on Biomonitoring."

The Boston Consensus panel presents their findings at the conference. (Photo courtesy of Boston SRP)

As part of the program, researchers recruited a panel of 15 lay people to learn about human biomonitoring, which included measuring lead, alcohol, and pesticide residues. Over two weekends, the panel considered technical, policy, ethical, and social issues. Their deliberations culminated in a three-day conference open to the public, where biomonitoring experts answered questions from the lay panel, and the lay panel presented their findings and final recommendations.

The conference drew a diverse group of people from Boston neighborhoods and nearby cities and towns. Results were shared with public health policy makers and scientists from around the country who conduct biomonitoring studies or deal with the issue in their work. The information was also shared with advocacy groups, public health agencies and organizations, industry trade groups, and others who are concerned with related policy.

Assessing PAH Levels During Tribal Salmon Smoking



Inside a tipi used for smoking salmon by the CTUIR. (Photo courtesy of Oregon State University SRP)

Anna Harding, Ph.D., at the Oregon State University SRP led a study that assessed PAH exposure pathways specific to a cultural tradition by engaging the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in the research process. The SRP Community Engagement Core conducted the study, which was the first to look at the health effects of PAH exposure resulting from traditional Native American salmon smoking. The CTUIR rely on smoked salmon for food and trading, and their smoking process involves exposing salmon fillets directly to smoke from smoldering wood for up to three days.

Before any materials or data were collected, all parties involved in the research signed a Material and Data Sharing Agreement that ensured equitable exchange of information that benefited the community without infringing on the study participants' privacy or on the sovereign rights of the tribe. Because there were no prior examples or templates for this type of document, the agreement template was published in Environmental Health Perspectives.

Tribal participants wore personal air samplers during the entire salmon smoking process, and urine samples were taken before, during, and after the event. Training videos produced by the Community Engagement Core showed the participants how to use the devices. The research team also used passive sampling devices in the smoking structures. Additionally, samples were collected from spring-run Chinook salmon that had been smoked in a wood shed or a tipi and using apple or alder wood.

Entrepreneurship Academy Teaches the Business of Environmentalism

Each year, the SRP sponsors the Green Technology Entrepreneurship Academy at the University of California-Davis. The event acts as a springboard to move green technology research out of the lab and into the world by educating researchers about the business opportunities associated with green technology.

The academy brings together scientists and engineers from several universities to attend a week of workshops and seminars on launching a successful green-tech company. Each participant comes to the academy with an elevator pitch for their potential company and learns more about the business side of environmentalism.

Venture capitalists, entrepreneurs, university faculty, industry executives, and angel investors serve as mentors and guest speakers, providing participants with the knowledge and networks to translate their research. Additional sponsors to the academy have included power companies and venture capital organizations as well as the Ewing Marion Kauffman Foundation, the academy's founding sponsor.

Participants benefit greatly from the opportunity to consider the new possibilities for the applications of their research as well as a chance to network with interested members of the business community.

Building Capacity of a Tribal EPA to Use Molecular Detection Technologies for Dioxins

Cheung, director of the 29 Palms Tribal EPA, is shown receiving Tukey's P450 HGRS cellular bioassay handed to him by Chen. (Photo Courtesy of UCSD)

When the 29 Palms Band of Mission Indians of California was concerned about dioxin contamination in water and soil, the tribal EPA wanted the ability to test for dioxins in its own lab. The 29 Palms Tribal EPA, which manages environmental protection programs on their reservation, partnered with the University of California-San Diego SRP and EPA Region 9 to gain the capacity to detect dioxins with state-of-the-art biomolecular assays.

Robert Tukey, Ph.D., and Shujuan Chen, Ph.D., from the University of California-San Diego, worked closely with the Tribal EPA to implement new laboratory protocols and field deployment procedures for assays that meet U.S. EPA guidelines. Thanks to a material transfer agreement between Tukey's lab and the 29 Palms Tribal EPA, Marshall Cheung, Ph.D., director of the 29 Palms Tribal EPA now uses the SRP-generated cytochrome P450 Reporter Gene System. This engineered reporter gene system cell line produces luciferase when the CYP1A1 gene on the chromosome is induced by toxic and carcinogenic organics such as dioxin, coplanar PCBs, and PAHs. The 29 Palms Tribal EPA is using this NIEHS SRP technology to develop a program for testing dioxin in soil and water.

This partnership is an example of ongoing work through the National EPA-Tribal Science Council, which provides a forum for Tribal communities and the EPA to identify environmental health problems and work together to design effective solutions.

CELEBRATING 25 Years

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